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JANINA JENTYS-SZAFEROWA

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JANINA JENTYS-SZAFEROWA

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1. PURPOSE AND METHOD

The morphological investigations on fossil fruits of the hornbeam in Poland, published in Vol. I nr 1 of „Acta Palaeobotanica" (1960), although made on a large material and using biometric methods, did not fully solve the problem of the history of the hornbeam in the geological epochs of the past. This led me to elaborate the same material in a different way. I wanted to make sure whether by investigating the anatomical structure of fossil fruits the conclusions drawn from morphological investigations could be confirmed, and to elucidate the questions to which the examination of the morphology of the fruits had given no answer.

The following conclusions were drawn from the morphological investigations.

1. In the Holocene climatic optimum and in the Riss-Würm Interglacial in Poland there grew a hornbeam of which the fruits had the same shape and the same intraspecific variability as the fruits of the recent species *Carpinus betulus.*

2. In the Pliocene there grew a hornbeam with fruits similar in shape to those of *Carpinus betulus,* but much smaller. The large percentage of fruits broader than they were long, a character now possessed only by the species *C. betulus,* was one of the points which determined them as belonging to the same type.

3. Besides the small nutlets, morphologically similar to those of *Carpinus betulus,* two large nuts from the Lower Pliocene were found at Krościenko. These were completely similar, both morphologically and as regards their dimensions, to the nutlets of the species *C. betulus* most frequently found to-day. This gave evidence that besides the small-fruited

hornbeam of C. *betulus* type, a hornbeam with fruits differing in no particular from those of to-day was already making a sporadic appearance in the Lower Pliocene. This suggested that the small-fruited hornbeam was little resistant to climatic changes and disappeared during the Ice Age, while the hornbeam with large fruits like those of to-day was resistant, survived the Ice Age and now grows in Poland as the only representative of the genus *Carpinus*.

4. In the Polish Pliocene there probably grew, besides the species of *C. betulus* type, species of hornbeam not found to-day, since they required a warmer climate. They did not, however, play any major part in the Polish Pliocene. On the basis of the morphological variability of samples from the Pliocene, I thought that perhaps species related to the present-day *C. orientalis, C. Tschonoskii* or *C. laxiflora* might come into play, but this was merely a supposition unsupported by proofs.

5. The fruits of the hornbeam which grew in the Polish Miocene differed from the contemporary species *C. betulus* both in dimensions and in shape. They were relatively narrower, and sharp-ended, recalling the fruits of the recent species *C. orientalis*.

I had certain doubts, which I wanted to clear up.

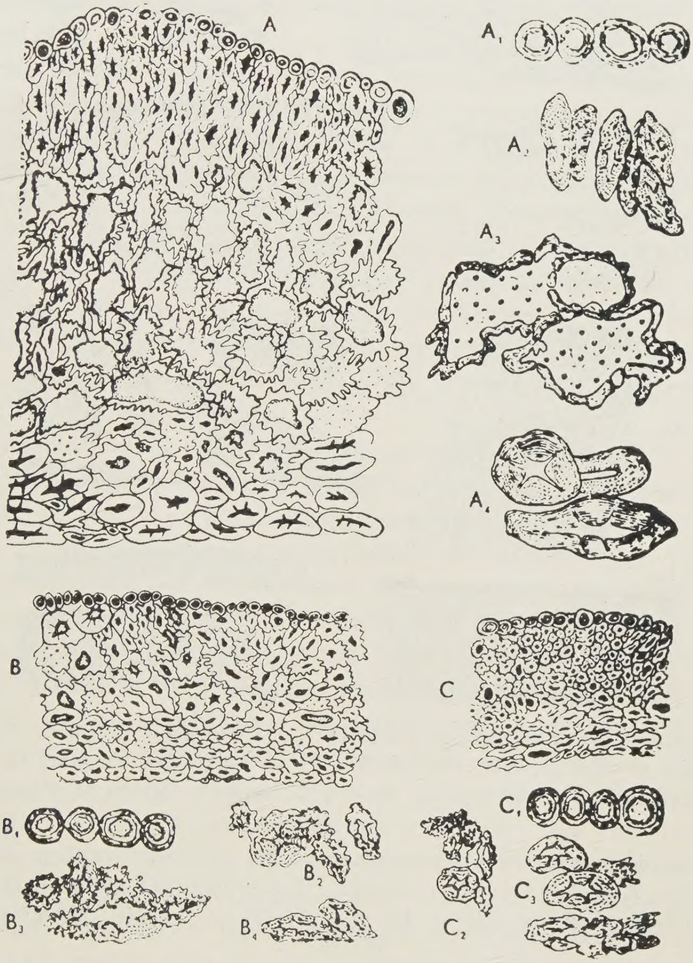
1. I wanted to make sure whether the Pliocene small-fruited hornbeams, which on the morphological basis I had reckoned as belonging to the type *C. betulus,* had the anatomical structure characteristic of this species.

2. I wanted to see whether it was possible, on an anatomical basis, to find out what other species of the genus *Carpinus* might have accompanied the small-fruited species *C. betulus* in the Pliocene forests of southern Poland.

3. Plentiful involucres of the *C. betulus* type from the Polish Miocene have been found, but so far none at all of the *C. orientalis* type; these involucres did not correspond to the shape of the hornbeam fruits from the Miocene found so abundantly in Poland, and of which the shape recalls that of the present-day species *C. orientalis*. This, among other reasons, was why I set myself the task of searching for diagnostic characters in the anatomical structure in order to determine to what species the fossil fruits belonged.

My anatomical investigations were based on the paper „Owoce rodzajów *Carpinus* i *Ostrya*" (The Fruits of the Genera *Carpinus* and *Ostrya*), by J. Jentys-Szaferowa and M. Białobrzeska (1953), which contains an analysis of the characters, both morphological and anatomical, of the fruits of the contemporary *Carpinus* and *Ostrya*.

Passing to the description of the anatomical studies on the fossil hornbeam nutlets, I shall not repeat the structural details of the contemporary fruits, already described in 1953. Only the photographs in Plate I, and the drawings of structural details of the pericarp of the fruits in Figs. 1—2 have been repeated from the paper mentioned. The fruits shown in Plate II were selected in such a manner that their breadths corresponded to the average breadth characteristic of the given species, so that the sections can be compared as regards dimensions. An exception was made only in the case of the species *Carpinus betulus*. Under a nutlet of average breadth,



g. 1. Transverse sections through pericarp: A — *Carpinus betulus*, B — *Carpinus* *roliniana*, C — *Carpinus orientalis*. Magnified × c. 120. A_1—A_4, B_1—B_4 and C_1—C_3, details of sections magnified × c. 200.

yc. 1. Przekroje poprzeczne przez perykarp: A — *Carpinus betulus*, B — *Carpinus* *roliniana*, C — *Carpinus orientalis*. Powiększone ok. 120 ×. A_1—A_4, B_1—B_4 i C_1—C_3, szczegóły przekrojów ok. 200 ×.

I have placed a photograph of a section of the narrowest nutlet of the species *C. betulus* in my material. The reason for this will be explained later.

A glance at Plates I and II will be enough to show that the species *Carpinus betulus* is distinctly different from the main species of hornbeam now existing. The differences, besides of course the dimensions of the nutlets, lie in the thickness of the pericarp, the clear ribbing of this, and the presence of cells with large lumens in the central part of the pericarp. Distinctly rounded vascular bundles in a relatively broad perigone, which increases the protuberance of the ribs, are also noticeable. These char-

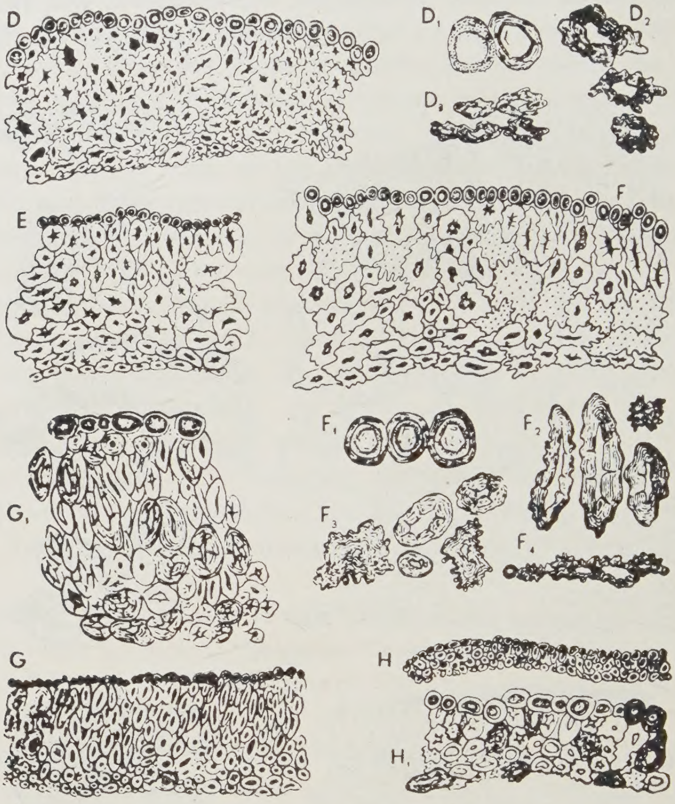


Fig. 2. Transverse sections through pericarp: D — *Carpinus laxiflora*, E — *Carpinus Turczaninowii*, F — *Carpinus Tschonoskii*, G — *Carpinus cordata*, H — *Carpinus japonica*. Magnified × c. 120. D_1—D_3, F_1—F_4, G_1 and H_1, details of sections magnified × c. 200.

Ryc. 2. Przekroje poprzeczne przez perykarp: D — *Carpinus laxiflora*, E — *Carpinus Turczaninowii*, F — *Carpinus Tschonoskii*, G. — *Carpinus cordata*, H — *Carpinus japonica*. Powiększone ok. 120 ×. D_1—$_3D$, F_1—F_4, C_1 i H_1 szczegóły przekrojów ok. 200 ×.

acters are irrespective of the dimensions of the nutlets, as is evident from the two photographs of sections of C. *betulus* placed one under the other. The upper photograph shows a section through a nutlet of average breadth, and the lower a section through the narrowest nutlet of this species which I have found. The breadth of this nutlet corresponds more or less to the average breadth of C. *caroliniana,* and was somewhat greater than the average breadth of the other species. The anatomical characters of the species C. *betulus* are clearly apparent in both sections, only the ribbing of the pericarp was not well marked in the broadest part of the small nutlet.

From the results of morphological investigations of recent nutlets of the genus *Carpinus* (1953), I had hoped that it would be possible to sort out from the mixture of fossil nutlets those of the species C. *betulus* on the basis of their measurements. This hope was in vain, since the Tertiary nutlets of the C. *betulus* type did not differ from other species in the dimensions of the fruits. These were described in detail in 1960, 1. The picture shown in Plate II, however, raised hopes that anatomical investigations might give better results. In order to determine the fossil material on the basis of the anatomy, careful observation of the degree to which the typical characters of the species C. *betulus* are preserved during fossilization was necessary.

I sought for answers to the questions already mentioned by examining successively older nuts belonging to the species C. *betulus,* first of all the Quaternary nutlets: subfossil nutlets from the Holocene, then from the Riss-Würm Interglacial, and finally from the Mindel-Riss Interglacial. Statistical studies did not demonstrate any essential morphological difference or any difference in local variability between these nutlets and those of the contemporary C. *betulus,* which assured me that the same species of hornbeam was growing in Poland throughout the Quaternary.

The fossil nutlets, both from the Quaternary and from the Tertiary, anatomically investigated were first measured by the method described in ,,Morphological Investigations of the Fossil *Carpinus*-Nutlets", p. 9, then photographed, and finally embedded in celloidine and cut transversely. All the sections from the apex to the base were arranged in order on slides and preserved in glycerine. Preparations fixed in glycerine-gelatine or Canada balsam were made from the most characteristic sections. In this way it was possible to link up the anatomical studies of the fossil nuts with their shape and size. All the photographs, both of the nutlets and of their sections, were made to the same scale, so that they could be compared. (Plates III—XIV).

2. THE NUTLETS FROM THE QUATERNARY

Anatomical studies were made of 11 subfossil nutlets from the Holocene, found at Krzeszów on the San (v. 1960,1 table 2). Since there was no doubt that these belonged to the species *C. betulus,* I deliberately chose specimens which clearly diverged morphologically from the average type for examination. This was to see whether even in extremes one in a thousand or sometimes in several thousands, the species to which they belong can be determined on the basis of the anatomical characters.

Photographs of 8 such nutlets from Krzeszów are shown in Plate III.

The nutlets shown on the left in Plate III were broader than they were long; their ratio of length to breadth was 0.8—0.9 (cf. J. Jentys-Szaferowa 1960,1, table 5). The nutlets on the right were 1.5 to 1.7 times longer than broad. Nutlets A and B had scarcely any ribbing at their broadest part; in the species *Carpinus betulus* this is a rare phenomenon. In addition, nutlet B had no thickening of the pericarp on the poles. Nutlet E was an extreme not only as regards the length-breadth ratio (the length was calculated only to the base of the style), but also as regards the situation of the broadest part (at 27 per cent of the length) and the apical angle (70°), and was more reminiscent of a nutlet of the genus *Ostrya* than the genus *Carpinus.* This was an abnormal nutlet, probably maldeveloped. Most of the nutlets had no perigone, which showed that they had been transported for some distance and the perigone had been destroyed on the way.

In spite of the great differences in the outward appearance of the nutlets, their anatomical structure aroused no doubts. All the extremes belonged to the species *Carpinus betulus,* as may be seen from the photographs of the sections placed alongside.

Five mechanically chosen nutlets from the Riss-Würm Interglacial were examined. Photographs of these are shown in Plate IV. The nutlet A in the upper part of the Plate was maldeveloped, like nutlet E in Plate III. In spite of this, the characters of the species *C. betulus* were clearly marked in the anatomical structure, (A_2 and A_3), as may be seen also in the sections of the next nuts. Nutlet E, like nutlet B in Plate III, had no ribbing of the pericarp at its greatest breadth. In transverse sections of the pericarp, however, its anatomical structure was still more clearly marked than is often the case in sections of recent *Carpinus betulus* nutlets. The perigone was preserved only in nutlet C, protruding over the ribs just as in the species mentioned above. Under the perigone a distinct layer of hollow cells, in which there were crystals of calcium oxalate, may be seen in the pericarp (cf. J. Jentys-Szaferowa and M. Białobrzeska 1953).

All the nuts were comparatively little flattened; it could be seen that they had not come from a distant geological epoch.

In the Mindel-Riss Interglacial (Plate V) a much more marked compression of the fossil material may be seen. The perigone was also flattened, so that the bundles in the ribs, which in the species C. *betulus* are usually rounded, sometimes appeared as oval. The compression is most of all marked by the disappearance of the internal hole of the pericarp. Sometimes the walls of this are in complete contact, as in nutlet E, although all the details of structure characteristic of the species C. *betulus* can be seen.

The material collected in Plates III—V gives a good example of the scale of variability of the morphological and anatomical structure of nutlets of the species *Carpinus betulus*. It may be seen that I occasionally met with nutlets in which one of the three characters described above as characteristic of the species C. *betulus* was not distinguishable, but the other two characters were always clearly marked; e. g. I found nutlets in which the ribbing of the pericarp was very faintly marked at the broadest part, or was entirely absent (Plate III, A and E, Plate IV, E), yet the thickness of the walls of the pericarp and the presence of cells with a large lumen in the medial part were so characteristic in these nutlets that it was quite certain that they should be reckoned as belonging to the species C. *betulus*.

In all I examined anatomically 11 subfossil nutlets, 5 from the Riss-Würm Interglacial, and 5 from the Mindel-Riss Interglacial, a total of 21 nutlets from the Quaternary.

Since the results of the investigations on the anatomy of the Quaternary nutlets showed that the characters typical of the species C. *betulus* were preserved during fossilization, there was no purpose in carrying out these studies on a larger material. My whole attention was therefore concentrated on the anatomical study of nutlets from the Pliocene which, on account of their small measurements, were very clearly distinguishable from the nutlets of the Quaternary.

3. THE NUTLETS FROM THE PLIOCENE

On the basis of detailed biometric examinations, I assigned the majority of the hornbeam nutlets from the Upper Pliocene at Mizerna and from the Lower Pliocene at Krościenko on the Dunajec in Poland to the C. *betulus* type. The typical character of the Pliocene type was only that the dimensions of the nutlets were considerably smaller than those of the C. *betulus* which grew in the Quaternary and is still growing to-day in Poland.

The grounds for my determination lay in the finding that 5.5 per cent of the nutlets from Mizerna and 4.5 per cent of those from Krościenko were broader than they were long. To-day such a high percentage of markedly broad nutlets may be found only in samples composed solely or almost solely of nutlets of the species *C. betulus.*

In order to make quite certain that my reasoning was correct, I endeavoured to assure myself in the first place that these broad Pliocene nutlets actually had the anatomical structure characteristic of the species *C. betulus.* There were 11 nuts of this description in the material from the Upper Pliocene. They were of varying length, as may be seen in table I.

Table 1
Tabela 1

LENGTH OF NUTLETS BROADER THAN LONG
DŁUGOŚĆ ORZESZKÓW SZERSZYCH OD SWEJ DŁUGOŚCI

Locality *Miejscowość*	Length in mm *Długość w mm*										n
	1,9	2,2	2,5	2,8	3,1	3,4	3,7	4,0	4,3	4,6	
Mizerna (Upper Pliocene)	—	—	1	0	2	1	2	3	1	1	11
Krościenko (Lower Pliocene)	1	1	0	0	3	4	1	1	—	—	11

Photographs of six broad nutlets from Mizerna are shown in Plate VI, and a seventh is placed at the top of Plate VII. As in Plates III—V, sections of the nuts magnified about 15 times and details of the sections magnified about 50 times have been placed beside the photographs. The photographs of the sections were not always taken exactly in the broadest part of the nutlet, because a section of this kind was not always suitable to photograph; none the less they contain all the characters of the anatomical structure of the given nut. The characters typical of the species *C. betulus* are here clearly marked; 1. the walls of the pericarp are relatively thick, 2. their thickness is not uniform, and the surface is distinctly ribbed, 3. there are cells with a large lumen in the medial part of the pericarp. These cells were sometimes very much flattened, so that the lumen was seen only as a black mark in the centre of the flattened cell, as for instance in the section D_3 in Plate VI, where there is seen every transition from cells with the lumen still distinct to cells with the lumen completely flattened. In some sections there may be seen the remains of the perigone with round, readily distinguishable bundles, usually situated in the convexities of the ribs.

The anatomical investigations completely confirmed the hypothesis that 5.5 per cent of the nutlets from the Upper Pliocene at Mizerna, broader than they were long, belonged to the *Carpinus betulus* type.

Further anatomical investigations of the fruits from the Upper Pliocene at Mizerna (for in my material only this sample represented the Upper Pliocene), were made in order to ascertain whether all the nuts belonged to the *betulus* type, or whether there was some admixture of any other type. I also wanted to see clearly what the variability of anatomical characters in nutlets from the Upper Pliocene was like, and also what were the differences in the degree of preservation of these characters in particular fruits.

The material from Mizerna consisted of 200 undamaged nutlets, examined biometrically, and a number of more or less damaged nuts. For the anatomical investigations I took some of the nuts which had been examined biometrically, in order to see whether it was possible to observe the external and internal structure of these fruits at the same time. My first intention was to make an anatomical study of about 100 nutlets from Mizerna, but by working in this fashion I should have been deprived of half my material which, although it would remain in the form of measurements, of photographs taken with the same magnifications and so possible to compare accurately, and of sections which have been all carefully preserved, yet would not have been available for other investigations, if some new and more efficient method of research on the historical evolution of plants were to be discovered. For this reason I did not wish the destruction of so much of my material. Besides, the effort and time necessary for this investigation would have been so great that the ending of my work, already so prolonged, would necessarily have been delayed. Nevertheless I took 76 nutlets from Mizerna for examination, including the 11 fruits broader than they were long already described. Four were damaged in sectioning, so that finally anatomical investigations were made on 72 nutlets, i. e. 36 per cent of the material.

In selecting the nutlets for investigation, I tried to include all classes of length in more or less the same proportion, as is seen from table 2. Nutlets of various shapes from broad to extremely narrow were chosen.

The results of the anatomical investigations of hornbeam nutlets from Mizerna have been set out in the lower part of table 2. I reckoned 69 nutlets, i. e. about 96 per cent, as belonging to a species of the *Carpinus betulus* type, and 3 nutlets, i. e. about 4 per cent, to a species with a different anatomical structure. The typical character of these three fruits was the uniformly narrow pericarp, not broadened on the poles, and with the external part composed of small cells with no distinct lumen. The lumina of the internal cells were slightly larger, and after compression were shown as a band of small lines parallel to the surface of the pericarp, but not reaching to the interior of the poles, as was characteristic of nuts

Table 2
Tabela 2

INVESTIGATIONS ON THE ANATOMY OF THE NUTLETS FROM THE UPPER PLIOCENE IN MIZERNA
BADANIA ANATOMICZNE ORZESZKÓW Z GÓRNEGO PLIOCENU W MIZERNEJ

	Length of nutlets in mm *Długość orzeszków w mm*													
	2,5	2,8	3,1	3,4	3,7	4,0	4,3	4,6	4,9	5,2	5,5	5,8	6,1	n
Investigated biometrically *Zbadano biometrycznie*	2	0	11	14	19	39	25	29	28	17	10	5	1	200
Investigated anatomically *Zbadano anatomicznie*	1	0	5	7	9	12	8	11	11	8	3	1	—	76

	The results of the anatomical researches *Wyniki badań anatomicznych*													
	2,5	2,8	3,1	3,4	3,7	4,0	4,3	4,6	4,9	5,2	5,5	5,8	6,1	n
Type *C. betulus* *Typ C. betulus*	1	0	2	7	9	10	7	10	11	8	3	1	—	69
Another type *Inny typ*	—	—	2	—	—	—	1	—	—	—	—	—	—	3
Damaged *Zniszczone*	—	—	1	—	—	2	—	1	—	—	—	—	—	4
	1	0	5	7	9	12	8	11	11	8	3	1	—	76

of the *C. betulus* type. Nutlet M in Plate VII and E in Plate XI is the representative of these fruitlets.

The nutlets determined in table 2 as belonging to the *Carpinus betulus* type were not uniform anatomically. In section, they exhibited a much greater variability than I have observed in nutlets from the Quaternary. The differences lay principally in the thickness of the pericarp. Besides nutlets with a notably thick pericarp, I also found some with a thin pericarp but having characters typical of *C. betulus*. It was difficult to decide whether these differences were caused by an uneven degree of fossilization, or whether they were a congenital character of a population of the Pliocene species. The division of these nutlets according to the thickness of the walls of the pericarp is shown in table 3, where it is seen that the thickness of the pericarp was not connected with the dimensions of the nut.

It was also not connected with its shape; evidence of this is given in Plate VII, which represents various types of pericarp found at Mizerna, from the very thick to the very thin. In both: the notably narrow nutlet B and the nutlet D, broader than it is long, the walls of the pericarp are very thick, while in the similar nutlets K and H they are thin. Again, as far as the thickness of the walls went, there was no distinct difference between nutlets H—L of the *Carpinus betulus* type and nutlet M, which I have assigned to „another" type.

Tabela 3
Table 3

THE CLASSIFICATION OF FRUITS OF THE TYPE *C. BETULUS* FROM MIZERNA (UPPER PLIOCENE) ON THE BASIS OF THE THICKNESS OF THEIR PERICARP

PODZIAŁ ORZESZKÓW TYPU C. BETULUS Z MIZERNEJ NA PODSTAWIE GRUBOŚCI ŚCIAN PERYKARPU

Wall of pericarp *Ściana perykarpu*	Length of nutlets in mm *Długość orzeszków w mm*												n
	2,5	2,8	3,1	3,4	3,7	4,0	4,3	4,6	4,9	5,2	5,5	5,8	
Very thick *Bardzo gruba*	1	0	0	2	1	1	0	1	3	3	1	1	14
Moderately thick *Średnio gruba*	—	—	1	1	3	4	5	5	2	1	—	—	22
Thin *Cienka*	—	—	1	4	5	5	2	4	6	4	2	—	33
	1	0	2	7	9	10	7	10	11	8	3	1	69

It was now to be established which of the thin-walled hornbeam fruits which I had examined anatomically in 1953 could give, in a fossil state, a picture similar to that seen in Plate VII in nutlet M_2 magnified about 15 times and in Plate XI, E_3 magnified about 50 times. Here it seems the most probable that the species is *Carpinus orientalis.* The nutlets of this, as follows from the descriptions in the paper of 1953 and from Fig. 1 C, and photograph B on Plate XI have a pericarp the exterior of which is constructed of small roundish cells with slightly folded thick membranes, while in the interior the cells are somewhat larger, and often elongated parallel to the surface. In this species also there are no differences in the structure of the pericarp on the poles or in the centre of a section of the nutlet (Plate II). In nutlets of the species *Turczaninowii, Tschonoskii* and *laxiflora* there is no such difference in the dimensions of the cells in the external and internal parts of the pericarp walls, and in addition there also appear characteristic groups of cells on the poles. In the species *C. caroliniana* a distinct ribbing of the pericarp appears. Hornbeams of the section *Distegocarpus* i. e. *C. japonica* and *C. cordata* and species of the genus *Ostrya* do not come into the question here, as their nutlets have an entirely different and very characteristic shape and anatomical structure.

As a result of my studies on the nutlets from the Upper Pliocene at Mizerna I ascertained that 96 per cent of the fruits of the genus *Carpinus* found there had an anatomical structure entirely similar to that of the present-day species *C. betulus*. The remaining 4 per cent had an anatomical structure similar to that of the recent fruits of *C. orientalis*. The length of these nutlets was 3.1—4.3 cm. Since the length of the nutlets of the contemporary *C. orientalis* is 3.12—4.75 cm, the dimensions of the nutlets of this type found at Mizerna would correspond to those of the recent nutlets.

Besides the nutlets from Mizerna, of a period which Professor Szafer assigned to the Upper Pliocene, 19 hornbeam nutlets, of which the external appearance showed that they had been transported from a considerable distance, were found in higher-lying strata in the same locality in a well about 3 metres deep which had been dug there. In these, the perigone was completely torn away, and often the outer part of the pericarp as well. A high degree of carbonization of the tissues could be seen in anatomical preparations. As regards their dimensions these nutlets corresponded to those of hornbeams from the Upper Pliocene, and their external and internal appearance gave evidence that in spite of coming from strata lying higher than the Upper Pliocene deposits, they were not younger than these. They were not therefore an indirect link between the nutlets from the Upper Pliocene and from the Quaternary already described, and perhaps they were lying on a secondary deposit. Photographs of nutlets from the well at Mizerna are shown in Plate VIII. They all belong to the type of *Carpinus betulus*.

The hornbeam nutlets from the Lower Pliocene at Krościenko which were studied anatomically were part of a sample of 300 nutlets characterized biometrically in 1960, 1. This was a sample which included materials determined by Professor Szafer as *C. betulus* L. *fossilis* and as *C.* cf. *Tschonoskii* Maxim. (Szafer 1947). I examined 63 of these, with particular reference to the smaller nutlets; Professor Szafer was undecided whether to assign these to the species *C. betulus fossilis* or to the species cf. *Tschonoskii*. The nutlets from Krościenko were more brittle and harder to section than those from Mizerna, so that 15 were damaged in cutting and the final studies were made on 48 nutlets (table 4).

Table 4
Tabela 4

INVESTIGATION ON THE ANATOMY OF NUTLETS FROM THE LOWER PLIOCENE IN KROŚCIENKO
BADANIA ANATOMICZNE ORZESZKÓW Z DOLNEGO PLIOCENU W KROŚCIENKU

	Length of fruits in mm *Długość orzeszków w mm*																		n
	1,9	2,2	2,5	2,8	3,1	3,4	3,7	4,0	4,3	4,6	4,9	5,2	5,5	5,8	6,1	6,4	6,7	7,0	
Investigated biometrically *Zbadano biometrycznie*	2	3	20	35	55	51	50	42	22	13	3	2	0	0	0	1	0	1	300
Investigated anatomically *Zbadano anatomicznie*	1	1	10	11	16	6	4	5	5	3	0	0	0	0	0	1	—	—	63

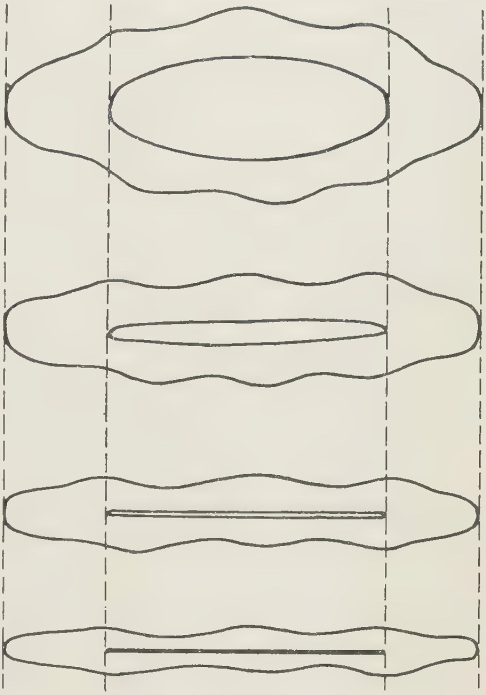
	The results of the anatomical researches *Wyniki badań anatomicznych*																		n
	1,9	2,2	2,5	2,8	3,1	3,4	3,7	4,0	4,3	4,6	4,9	5,2	5,5	5,8	6,1	6,4	6,7	7,0	
C. betulus type *Typ C. betulus*	1	1	4	8	9	4	4	5	5	3	0	0	0	0	0	1	—	—	45
Another type *Inny typ*	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Damaged *Zniszczone*	—	—	3	3	7	2	—	—	—	—	—	—	—	—	—	—	—	—	15
	1	1	10	11	16	6	4	5	5	3	0	0	0	0	0	1	—	—	63

As in the investigations on the material from Mizerna, I tried first of all to assure myself that the 11 nutlets broader than they were long found at Krościenko had the anatomical structure characteristic of nutlets of the *C. betulus* type. The results were similar to those of the examinations of the nutlets from Mizerna. In spite of the sometimes very small dimensions of these nutlets (table 1), they certainly belonged to the type of *C. betulus*. Hence it was logical to conclude that the majority of the Krościenko nutlets must also belong to this type. Photographs of 7 nutlets broader than they are long are given in Plate IX.

Plate IX, when compared with Plate VI, showing the analogous nutlets from Mizerna, will help to make clear the anatomical changes in the fossil hornbeam nutlets occasioned by lying in the ground for so long. The difference between the subfossil material and the nutlets from the Riss-Würm and Mindel-Riss Interglacials consists mainly in the fact that the lumen in section becomes markedly smaller as the geological age of the nutlets rises, while the thickness of the walls is insignificantly lessened, but the difference in the thickness of the walls between the nutlets broader than they are long from the Upper Pliocene at Mizerna and the Lower Pliocene at Krościenko is striking. The fruitlets of the genus *Carpinus* found at Krościenko exhibit a far-advanced degree of fossilization, shown not only in their greater compression but in distinct defects in the organic material, so that the walls of the nutlets became much thiner. This is particularly striking if the nutlets of the same dimensions shown in Plates VI and IX are compared. Outwardly, they look the same and do not betray any such differences in the degree of fossilization as are shown in the sections. The flattening of the nutlets is also shown clearly in the lumina of the large cells of the pericarp. Comparing photographs of particular sections, magnified about 50 times, it is seen that in the Mizerna nutlets these lumina are still quite clear, while in the Krościenko nutlets they are usually outlined only as dark bands, penetrating far into the poles of the sections. If this picture is compared with the section of *Carpinus betulus* in Plate II and in the Plates III—V, it is clear that these bands are nothing else but the flattened cells with large lumina which in the recent species *C. betulus* are found in the medial layer of the walls of the pericarp, and on the poles of the nutlets fill a large part of their interior.

Attention is called to the thickness of the pericarp on the poles, markedly greater than on the sides, in sections C_3—G_3 of Plate IX. This is in connection with the lateral compression of the nutlets (cf. Fig. 3 and the paper from 1960, 1, p. 7).

Another thing which is striking in Plates VI and IX is the dimensions of the nutlets broader than they are long. Almost all the classes of size in these nutlets are found both at Mizerna and at Krościenko, as is clearly seen from table 1. One of the two smallest nutlets found at Mizerna, 2.4 cm in length, and one of the two smallest found at Krościenko, 1.9 cm in length, were broader than their length and when studied anatomically exhibited characters of the species C. *betulus* in structure (Plate VII, A and Plate IX, A). This gives evidence that not only the larger nutlets at Krościenko belonged to the C. *betulus* type, but also the smaller ones. When Professor Szafer hesitated whether the small nutlets from the Lower Pliocene at Krościenko should not be assigned to the C. *betulus* type and not, as originally supposed, to C. cf. *Tschonoskii*, he was right. Besides the nutlets greater in breadth than in length I also examined anatomically 37 nutlets from Krościenko, of which 34, i. e. 92 per cent, I assigned to the C. *betulus* type, and 3, i. e. 8 per cent, exhibited a structure similar to C. *orientalis* (Plate X, M and P). In this sample of nutlets, however, none were found that resembled the recent C. *Tschonoskii* in their anatomical structure.



Ryc. 3. Diagram representing the effect of vertical compression in sediment on a pericarp of a *Carpinus betulus* fruit (cf. J. Walton 1936).

Ryc. 3. Schemat przedstawiający efekt pionowego ucisku osadów na perykarp orzeszka *Carpinus betulus* (por. J. Walton 1936).

It is interesting to compare the analogous Plates VII and X. Both demonstrate the transition from the thick-walled to the thin-walled nutlets, found in the deposits mentioned. A comparison of these Plates shows that at Krościenko there did not appear nutlets with such thick walls as at Mizerna. When compiling table 5, similar to table 3, I did not insert the category ,,Very thick pericarp'', but introduced a new category, ,,Very thin pericarp''. This is connected with the further-advanced fossilization.

In Plate X, the section of one of the two large nutlets found at Krościenko is of special interest. These nutlets, 6.4 and 7.0 cm in length, were those of which I wrote in the biometrical part of this paper (1960) that on the basis of the measurements they could not belong to the same population as the other Pliocene nutlets. In spite of the partial absence of the perigone, the nutlet examined is very well-preserved morphologically, and the extent to which fossilization has advanced can only be seen in section. There is no doubt that this nutlet belongs to the *C. betulus* type.

Observation of the sections of Krościenko nutlets, of which some are shown in Plates IX and X, led me to conclude that the difference noted in the thickness of the walls of nutlets from the Upper Pliocene at Mizerna were probably not caused by any essential differences in thickness in the population of that time, but by the varying degree of fossilization and compression in the fruits. The preservation of the perigone both in nutlets with thick and with thin pericarps (cf Plates VI and VII, J_2) shows that these nutlets were not transported from a distance and were lying on the primary deposit; yet the period during which they were deposited must have lasted for a long time, and the conditions under which the processes of fossilization occurred must have varied, so that the differences in the thickness of the walls may have arisen from this. Of course, this is only a supposition.

Table 5
Tabela 5

THE CLASSIFICATION OF FRUITS OF THE TYPE *C. BETULUS* FROM KROŚCIENKO (LOWER PLIOCENE) ON THE BASIS OF THE THICKNESS OF THEIR PERICARP

PODZIAŁ ORZESZKÓW TYPU C. BETULUS Z KROŚCIENKA NA PODSTAWIE GRUBOŚCI ŚCIAN PERYKARPU

Wall of pericarp *Ściana perykarpu*	1,9	2,2	2,5	2,8	3,1	3,4	3,7	4,0	4,3	4,6	4,9	5,2	5,5	5,8	6,1	6,4mm	n
Moderately thick *Średnio gruba*	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	2
Thin *Cienka*	1	1	3	5	7	3	4	4	4	3	—	—	—	—	—	1	36
Very thin *Bardzo cienka*	—	—	1	3	1	0	0	1	1	—	—	—	—	—	—	—	7
	1	1	4	8	9	4	4	5	5	3	0	0	0	0	0	1	45

Besides the material already described, there were still in the collections of the Botanical Institute 25 of the nutlets sorted out by Professor Szafer from the Pliocene deposits at Krościenko and determined as *C. laxiflora* (Szafer 1947). I studied these biometrically and compared the arithmetic means of their characters with those of the species *C. betulus*. The fossil nutlets proved to be closer in shape to *C. betulus* than to the contemporary species *C. laxiflora*, but the low situation of the broadest part and the fairly acute angle of their apex were characteristic of the species *laxiflora.*

Since I was already convinced that the determination of fossil nutlets of the genus *Carpinus* by their external appearance is fallacious, I made sections of 6 nutlets, determined by Professor Szafer as belonging to *C. laxiflora*, in order to examine their anatomical structure. The results were interesting. One of the nutlets examined had a structure typical of *C. betulus*, a second should probably have been assigned to the same species, a third had the characteristic structure of the *orientalis* type, while the other three presented a picture which I have hitherto never encountered. They were not flattened, thin-walled, and in transverse section were not oval but tapering sharply towards the two poles, so that in section they resembled the shape of a lemon (Plate XI, G). A similar picture was given by sections of the recent species *C. laxiflora* and *C. Tschonoskii* (v. Plate II). It was difficult for me to judge to which of these species my three fossil nutlets approached most closely, since their internal structure was rather damaged. We have, however, a proof that either both or one of these species grew sporadically in the forests of the Lower Pliocene in the foothills of the present Carpathians.

In this case, the eye of an experienced botanist was able to distinguish something foreign to the *C. betulus* type in the shapes of the majority of the nutlets described.

The result of the anatomical studies of the Pliocene nutlets determined by Professor Szafer as *C. laxiflora* led me to examine by the same method a sample of several nutlets, assigned to the Pliocene type of *C. Tschonoskii*, found in the Palaeobotanical Museum of the Botanical Institute. These nutlets were not included in the sample of 300 nutlets from Krościenko which had previously been examined biometrically.

Anatomical studies showed that out of 8 of these nutlets 6 belonged to the *C. betulus* type, and 2 to the *C. laxiflora* or possibly to the *C. Tschonoskii* type, of which I have written above. This was a further proof that in southern Poland during the Pliocene there grew hornbeams which do not grow there now.

Since the materials from Krościenko which I obtained for detailed elaboration had already been sorted and some of them already distributed as exhibition material to the Botanical Institute and to the Geological Institute in Warsaw, it was difficult to determine the exact percentage relation in which these species of hornbeam, no longer extant in our country, grew in the Polish Pliocene forests. This percentage, however, could not have been high.

4. THE NUTLETS FROM THE MIOCENE

As I have already written in the biometrical part, the Miocene hornbeams were represented in my research by two samples. One came from the Middle Miocene at Gliwice in Silesia, and the other (probably a little younger) from the sediments deposited at the foot of the Tatras on the slopes of the hill named „Domański Wierch". The age of these deposits has not been definitively determined, and the flora found there has not yet been elaborated.

The nutlets from the Miocene salt deposits at Wieliczka in my possession were so few that their investigation can be only of orientational significance.

The result of the biometrical studies left unanswered the question of what species the nutlets from Gliwice and Domański Wierch belonged to. The nutlets in both samples were morphologically very like those of *C. orientalis,* which seemed to me rather strange because only involucres of the *C. betulus* type had previously been found in Poland, but none at all of the *C. orientalis* type (Jentys-Szaferowa 1958, 1960). After carrying out anatomical investigations which indicated that probably the *C. orientalis* type occurred in Poland during the Pliocene, although playing a very small part in the forests of that time as compared with the *C. betulus* type, it seemed more possible for the *orientalis* type to have occurred in the Miocene forests, and so the result of the anatomical studies on the Miocene fruitlets of the genus *Carpinus* was of all the more interest to me.

I made anatomical studies of 13 nutlets from the Tortonian Flora at Gliwice. Photographs of 11 of these and of their sections are shown in Plate XII. The picture gives an idea of the degree of fossilization of the hornbeam fruitlets which had been lying in the ground since the Middle-Miocene. In spite of the well-preserved morphological structure of the nutlets, in transverse section they look like narrow bands almost entirely devoid of any traces of their original anatomical structure. Careful observation of the nutlets under high magnification, using a good microscope, showed that their structure is similar to that of the fossilized nutlets from the Lower Pliocene which I assigned to the *C. betulus* type. The black marks, the remains of cells with large lumina, are here particularly characteristic. These marks enter the distincly broad poles in the sections. Out of the 13 nutlets examined, I did not find even one of the *C. orientalis* type, although the external appearance of the fruitlets suggested that they belonged to this. Though after anatomical examination of only 13 nutlets from Gliwice it cannot be said that solely the *C. betulus* type appeared there, it was certainly distinctly predominant.

The finding of nutlets of the *C. betulus* type in Middle Miocene deposits in Silesia is in accordance with the previous discoveries of fruit scales of the genus *Carpinus*, as at a distance of 200 km from Gliwice in this province there is the locality of Sośnica (Schossnitz), well-known to palaeobotanists, where Goeppert made the richest finds of hornbeam involucres from the Middle Miocene so far known. I drew 27 of these involucres in a paper published in 1958. They are all of the *C. betulus* type, with the exception of two, which show a certain similarity to the *C. caroliniana* type. It would not be strange, therefore, if a hornbeam of the *C. betulus* type also grew at Gliwice in deposits not much older than those at Sośnica. Only the fact that the shape of the Miocene nutlets from Gliwice does not coincide with that of the *C. betulus* type from the Pliocene at Mizerna and Krościenko seems strange. Indeed, nutlets of the *C. betulus* type sometimes occurred there also in a narrow and sharp-ended form, and even at Mizerna the average ratio of length to breadth was much higher than in the present species *C. betulus,* but I also found other shapes as well there, and a significant percentage appeared even of nutlets broader than they were long (Plates VI and IX).

Out of the 218 nutlets found at Gliwice only one was broader than long, i. e. about 0.5 per cent (Plate XII A), three were as broad as long, and the rest were shaped like nutlets B—H in Plate XII.

Having ascertained that the comparatively narrow nutlets with sharp ends found at Gliwice belonged to the *Carpinus betulus* type, in spite of their external similarity to the *orientalis* type, the determination of fossil nutlets of the genus *Carpinus* solely on grounds of shape is seen to be fallacious. How it could have happened that nutlets of two different species which can now be very readily distinguished anatomically and morphologically could have been similar in shape in the Miocene, however, is a question that still remains to be answered. Here there is no question of a lack of difference in the size, as we already know that in the Tertiary hornbeams of the *C. betulus* type had much smaller nutlets than in the Quaternary, and so at that time there may not have been any distinct difference in size between fruits of the *betulus* and *orientalis* types.

A certain light has been thrown on this problem by Grossheim's note on the recent Caucasian hornbeams, assigned to the species *C. betulus* (1940). This author studied the fruits of 75 specimens of the species *C. betulus* in Central Europe, ranging from the Lower Rhône to beyond Czernichów, taking one fruit from a tree, and on the other hand a similar sample from the Crimea, the Caucasus and Asia Minor, and found that the nuts of these last are much narrower and sharper-ended. This character is, in Grossheim's opinion, so typical that although the Caucasian hornbeams are not distinguished from the species *C. betulus* as regards other characters, yet it is sufficient to rank the Caucasian hornbeams as a separate species, to which he gave the name of *Carpinus caucasica* (Fig. 4, Plate XIV).

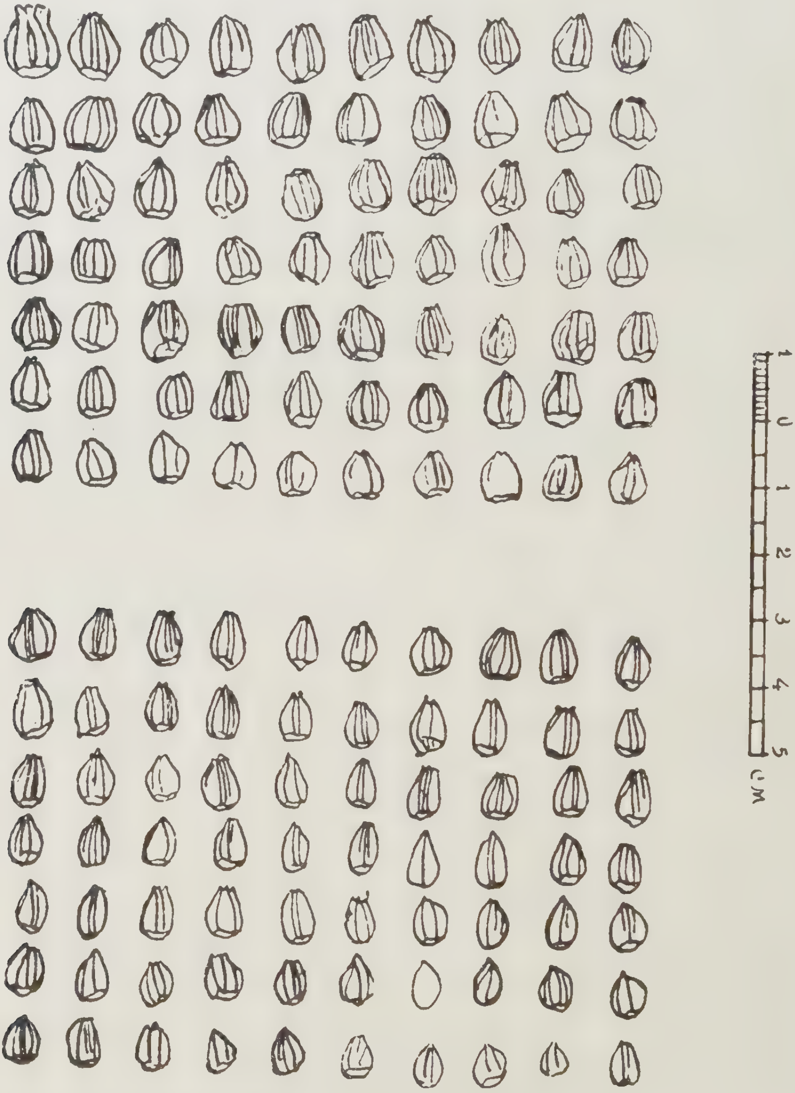


Fig. 4. Above, nutlets of *Carpinus betulus* L. collected from 70 trees (v. Fig. 5, D). Below, nutlets of *Carpinus caucasica* A. Grossheim, collected from 70 trees (v. Fig. 5, E). From Grossheim.

Ryc. 4. U góry orzeszki *Carpinus betulus* L. zebrane z 70 drzew (patrz ryc. 5, D). U dołu orzeszki *Carpinus caucasica* A. Grossheim zebrane z 70 drzew (patrz ryc. 5, E). Według Grossheima.

The mean values of the characters of *C. betulus* and *C. caucasica* measured by Grossheim are as follows:

Species	Number of trees	Number of fruits	Length of fruits	Breadth of fruits	Length-breadth ratio
C. betulus	75	75	6,22 mm	5,9 mm	1,1
C. caucasica	75	75	5,78 mm	4,45 mm	1,3

Grossheim's observation gives much food for thought. Evidently, besides the local variability, of which I wrote in my morphological studies on the fruits of *Carpinus,* the species *C. betulus* has a variability linked with geographical situation over the area of its range. Hence the narrow-fruited form *C. caucasica* described by Grossheim occurs over the whole south-eastern limit of the range of this tree. It is difficult to say at present whether the local differences in the breadth of the nuts which I demonstrated in 1960 in Figs. 2 and 5 also occur over this area. If, however, there are any, these vary on another scale, viz., the scale of more or less narrow fruits with relatively sharp apices.

The opposite of the narrow-fruited hornbeam, which is perhaps an ecological type connected with a warmer climate, is probably the hornbeam with relatively broad and blunt-ended fruits which occupies the northern parts of the range and is connected with a more severe climate. When I was working on the variability of the species *C. betulus* for the paper published in 1953 I elaborated a whole series of local samples from various parts of Europe. At that time it struck me that samples coming from places lying in the south of Europe or in the west not far from the Atlantic usually had narrow sharp-ended nutlets, while samples from the north-eastern part of the range had broader nutlets. Similarly, in Switzerland, the higher the locality where the sample was gathered, the broader the nuts. I should have liked to have shown this on a map, but my material was too small for such a generalization and so I confined myself to describing this observation in 1953. It has now been shown that my former supposition was probably correct.

On the map shown in Fig. 5, I have marked on the whole range of *C. betulus* two areas. One of these is the area in which, according to Grossheim, *Carpinus caucasica* occurs (E), and the other is the Polish area from which I measured a sample of 400 nutlets of *C. betulus* (B). This area lies near the northern limits of the range of this species. Two completely different types of *C. betulus* fruits appear in these areas; narrow or sharp-ended in the south, broad and blunt-ended in the north. Although within Poland there are local variations, which I presented in Fig. 5 in 1960, the general type differs from that in the south.

Let us now turn our thoughts to the shore of a great bay of the mid-Miocene Mediterranean, i. e. the Parathetys. This shore ran through Poland along the line Wieliczka-Gliwice-Sośnica, where now rich Miocene flora are found. If at that time *C. betulus* had the same involucres and anatomy of its fruits as the *C. betulus* of to-day, it might also have had a similar

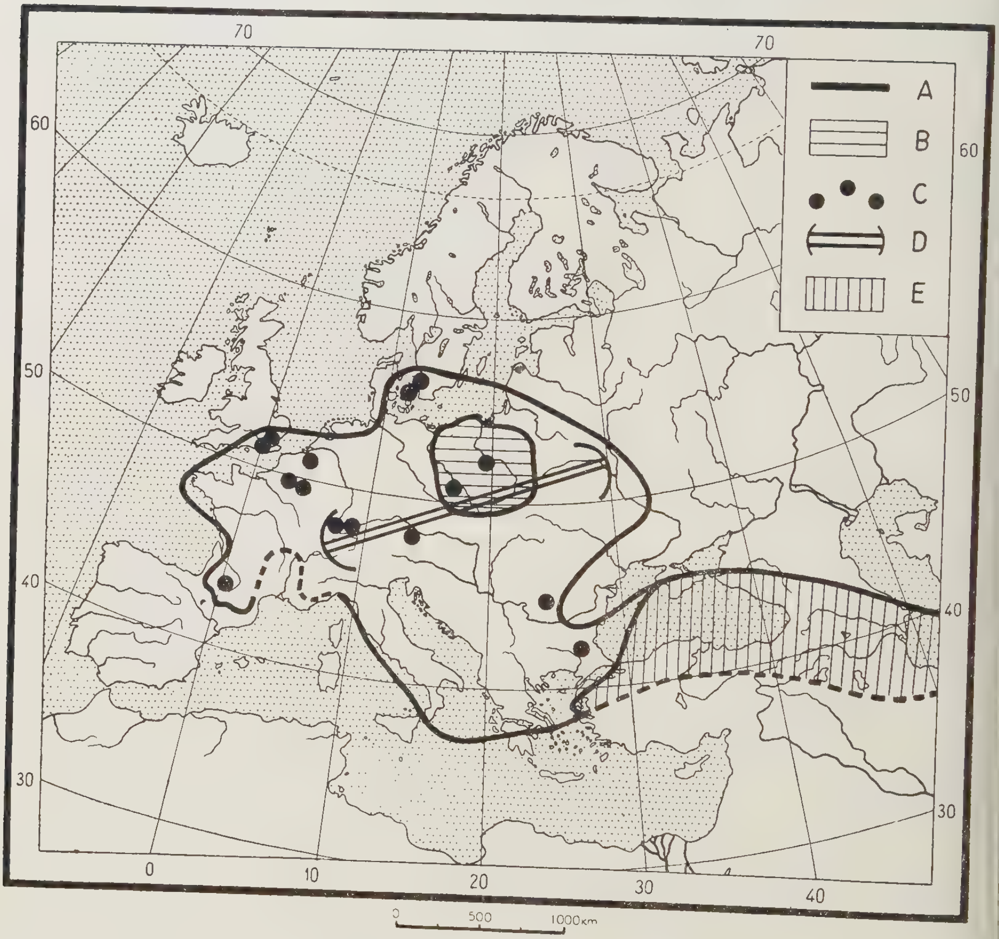


Fig. 5. A — Area of the species *C. betulus*. B — The Polish region. C — Local samples of *C. betulus* investigated by J. Jentys-Szaferowa (1953). D — The region from which the 75 trees of *C. betulus* L. investigated by Grossheim came (v. Fig. 4). E — The region from which the 75 trees of *Carpinus caucasica* A. Grossheim came (v. Fig. 4 and Plate XIV).

Ryc. 5. A — Zasięg gatunku *C. betulus*. B — Terytorium Polski. C — Stanowiska *C. betulus* zbadane przez J. Jentys-Szaferową (1953). D — Terytorium, z którego pochodziło 75 drzew *C. betulus* L., zbadanych przez Grossheima (patrz. ryc. 4). E — Terytorium, z którego pochodziło 75 drzew *Carpinus caucasica* A. Grossheim (patrz ryc. 4 i Tablica XIV).

local variability, and in that case it would not be strange if on the Tertiary bay of the Mediterranean there had grown a form of hornbeam like that growing to-day by the Mediterranean and Black Sea, a form probably connected with a warmer and humid climate.

At Sośnica Goeppert found many hornbeam sheaths and leaves, but no fruits. By very careful washing of the material from Sośnica, however, sometimes hornbeam fruits may also be found, often well-preserved, as for instance the nutlet in Plate XIV. In shape they are as relatively narrow and markedly tapering as the nutlets of the *C. betulus* type from Gliwice, which supports my hypothesis.

I made anatomical studies of 12 fruits of the genus *Carpinus* found in the Miocene deposits on Domański Wierch at the foot of the Tatras. They were all longer than they were broad, and sharp-ended. Their walls were so compressed that they appeared as thin plates and often disintegrated while being cut; the ribs were preserved only in a few specimens. Observation of the sections under high magnification showed that some of these fruits belonged to the *C. betulus* type (Plate XIII, D—F and H—L); it was difficult to determine the others, because their anatomical structure was indistinct. Some of them showed a resemblance to *C. orientalis*. On Domański Wierch there was perhaps not such an uniform type of hornbeam fruit as at Gliwice.

I had for investigation only 5 nutlets from the Miocene salt deposits at Wieliczka near Cracow, the age of which has been determined as the Middle or Lower Miocene. Photographs of these nutlets are shown in Plate I, 1960. They have been described by J. Zabłocki under the name of *Carpinus polonica*. They had the character in common that they were not flattened and even nutlet J_2 was so well-preserved that it gave a very clear idea of what the fruits of the Miocene hornbeams once looked like. Besides these, I had a few badly damaged nutlets, from which I endeavoured to make sections. They were so brittle, however, that they fell to pieces, although I had attempted to fix them before sectioning by saturating them with a solution of celloidine. A fragment of these sections is shown in Plate XIV, A.

The picture of the sections of nutlets from Wieliczka was different from that of the flattened nutlets from other Tertiary deposits. The walls of the fruitlets were comparatively thick, and full of orifices, so that they looked like coarse lace. The places through which the light came were not, however, the interiors of cells, but chiefly hollow spaces between cells separated from one another by decaying tissue. In the outer part of the pericarp these cells were not very large and were unflattened, and in the inner part there was a layer of cells elongated parallel to the surface. It is difficult to say to what species the fruits from Wieliczka belonged, except that their shape resembled the narrow, sharp-ended fruits of the *C. betulus* type found at Gliwice and the fruits, already described, from Sośnica, where the numerous hornbeam fruit involucres show that only the *C. betulus* type grew there.

5. SUMMARY

Summing up the results of my research on fossil nutlets, I have come to the following conclusions:

1. During the Polish Tertiary, the predominating hornbeam was of the *C. betulus* type, with fruits having the same structure as the recent species, but markedly smaller and often narrower.

2. The *C. betulus* type occurred in the Miocene forests either alone as at Gliwice or Sośnica, or mixed with other species, as at Domański Wierch, one of them probably belonging to the *orientalis* type.

3. In the Lover Pliocene, besides the prevalent *C. betulus* type, a small percentage of a hornbeam of the *orientalis*, and perhaps *Tschonoskii* or *laxiflora* type was preserved in the forests in areas now belonging to Poland.

4. I found no fruits at all of the *laxiflora* or possibly *Tschonoskii* type from the Upper Pliocene, but only fruits of the *Carpinus betulus* type, in the small-fruited form, and very occasional fruits of the *orientalis* type.

5. Besides the species mentioned, as early as the Lower Pliocene, a large-fruited species of *Carpinus betulus*, not differing in the least from the recent species, occurred, but only in very small numbers. It is probable that the Tertiary species of *Carpinus betulus* type, characterized by small fruits, was connected with the warmer climate and did not survive the Ice Age. The large-fruited *Carpinus betulus* survived the Ice Age in Europe and in the Holocene spread over almost all this region.

6. Fruits from the Quaternary did not differ in dimensions and in anatomical structure from the recent fruits of *Carpinus betulus*.

As may be seen from this presentation, the results of the anatomical studies have coincided with those of the morphological. However they have made a further contribution to our knowledge of the Polish fossil hornbeams, since on the one hand they have thrown some light on the species of hornbeam now foreign to the Polish flora but which were still growing in Poland, though rarely, in the Pliocene, and on the other hand have strengthened our conviction that the species of *C. betulus* type is an old one which was growing in abundance in Poland during the Middle Miocene and probably still earlier.

These anatomical studies have also shown how fallacious the determination of fossil hornbeam fruits may be if made only on the basis of their morphology, and on the other hand how important it is when doing research on fossil materials to consider the ecological and geographical aspects of the population, to which the investigated plants once belonged.

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STRESZCZENIE

1. CEL I METODA PRACY

Badania morfologiczne nad kopalnymi orzeszkami grabu w Polsce (1960) nie rozstrzygnęły w pełni historii tego drzewa. To mię skłoniło do opracowania tego samego materiału z punktu widzenia budowy anatomicznej. Miałam nadzieję, że uda się może wyjaśnić na tej drodze zagadnienia, na które badania morfologii orzeszków nie dały odpowiedzi, a równocześnie potwierdzić wnioski wysnute z badań morfologicznych.

Wyniki badań morfologicznych przedstawiały się następująco:

1. W holocenie i w interglacjale Riss-Würm rósł w Polsce grab, którego owoce miały ten sam kształt i tę samą zmienność wewnątrzgatunkową, co dzisiejszy gatunek *C. betulus.*

2. Orzeszki grabu plioceńskiego miały ten sam kształt, co *C. betulus,* ale były znacznie mniejsze.

3. Oprócz powyższych rósł w pliocenie sporadycznie grab o owocach nie różniących się rozmiarami od współczesnego *C. betulus* oraz prawdopodobnie w małym procencie gatunki typu *C. orientalis* i *C. Tschonoskii,* względnie *C. laxiflora.*

4. Mioceńskie orzeszki grabu były przeciętnie nieco dłuższe od poprzednich, węższe, ostro zakończone i przypominały rozmiarami i kształtem orzeszki dzisiejszego *C. orientalis.*

Badania anatomii orzeszków miały na celu:

1. potwierdzić przynależność małych orzeszków z pliocenu do typu *C. betulus.*

2. Określić przynależność gatunkową innych grabów, które rosły sporadycznie w pliocenie, oraz ich ewentualny stosunek procentowy.

3. Określić przynależność gatunkową mioceńskich grabów o wąskich, ostro zakończonych orzeszkach.

Podstawą, na jakiej się opierałam w badaniach anatomicznych, była rozprawa, którą ogłosiłam w r. 1953 wspólnie z mgr M. Białobrzeską. Fotografie orzeszków najważniejszych współczesnych gatunków grabu zamieściłam na Tablicy I, ich przekroje zaś na Tablicy II. Szczegóły budowy anatomicznej znaleźć można na ryc. 1 i 2.

Na Tablicach I i II widać, że gatunek *C. betulus* różni się wyraźnie od głównych gatunków żyjących dziś grabów. Składają się na to, poza rozmiarami orzeszków: szerokość perykarpu, jego żeberkowanie oraz obecność komórek o dużych światłach w jego środkowej części. Poza tym zaznaczają się wyraźnie okrągławe wiązki w stosunkowo szerokim perygonie. Cechy te są niezależne od rozmiarów orzeszków (Tablica II, A_1—A_2). To budziło nadzieję, że gatunek *C. betulus* będzie można określić w stanie kopalnym. Aby jednak określać na podstawie anatomicznej materiały kopalne, konieczna była dokładna obserwacja, w jakim stopniu zachowują się charakterystyczne cechy gatunku *C. betulus* przy fosylizacji.

Odpowiedzi na powyższe pytanie szukałam badając coraz starsze orzeszki należące do gatunku *C. betulus*, analogicznie do tego jak postępowałam przy badaniach biometrycznych. Wyniki badań ilustrują Tablice III—XIV, na których zestawiłam fotografie kopalnych orzeszków i ich przekrojów. Są one robione w tej samej skali, dzięki czemu są ze sobą porównywalne.

2. ORZESZKI Z CZWARTORZĘDU

Porównując stopniowo współczesne orzeszki najpierw z materiałem z holocenu, a potem z młodszym, a wreszcie ze starszym interglacjałem — stwierdziłam, że wskutek większego spłaszczania coraz starszych orzeszków zanikało przede wszystkim puste wnętrze perykarpu. Natomiast w ścianach perykarpu zmiany były niewielkie. Poza tym można było zaobserwować skalę wahań cech charakterystycznych dla gatunku *C. betulus*. Szczegółowe opisy znajdują się w objaśnieniach do Tablic III—V.

3. ORZESZKI Z PLIOCENU

Na podstawie badań biometrycznych zaliczyłam większość orzeszków grabu, znalezionych w górnym pliocenie w Mizernej i w dolnym pliocenie w Krościenku do typu *C. betulus*, mimo ich znacznie mniejszych rozmiarów. Podstawą tego określenia było znalezienie w Mizernej 5,5%, a w Krościenku 4,5% orzeszków szerszych od swej długości, co dziś jest charakterystyczne jedynie dla gatunku *C. betulus*. Orzeszki te spotykałam w materiale kopalnym w prawie wszystkich klasach długości (tabela 1). Zbadane anatomicznie, wykazały cechy budowy charakterystyczne dla *C. betulus*, co potwierdziło hipotezę o przynależności większości orzeszków grabu z naszego pliocenu do typu *C. betulus* (Tablice VI i IX).

Dalsze badania anatomiczne były robione na pozostałych orzeszkach plioceńskich, zbadanych poprzednio biometrycznie. Wybierałam przy tym rozmyślnie orzeszki różnych kształtów i różnych rozmiarów (tabele 2 i 4, Tablice VII i X). Miało to na celu obserwowanie u typu *C. betulus* zmian anatomicznych, wywołanych fosylizacją, związanie budowy wewnętrznej z kształtem orzeszków i ewentualne określenie innych gatunków grabu, które rosły w naszym pliocenie. W wyniku przyszłam do wniosku, że:

1. Do typu *C. betulus* należały orzeszki różnych rozmiarów od szerokich i tępych do wąskich i ostro zakończonych. Tu należał również duży orzeszek, 6,4 mm długi, znaleziony w Krościenku.
2. Sprasowanie wymienionych orzeszków odbijało się nie tylko na ich

wnętrzu, ale i na ich ścianach. Wskutek jednostronnego ucisku zaznaczała się coraz większa różnica między grubością perykarpu na bokach i na biegunach przekrojów (ryc. 3). Równocześnie światła komórek, leżących w środkowej części perykarpu, zaczynały zanikać, a w ich miejsce pojawiały się ciemne prążki, wchodzące głęboko w bieguny przekrojów (Tablica VI, B_3, D_3, Tablica IX, D_3—G_3).

3. W materiałach plioceńskich obserwowałam znacznie większe różnice w grubości ścian perykarpu poszczególnych orzeszków niż w materiałach czwartorzędowych. Trudno było zadecydować, czy te różnice były cechą charakterystyczną dla plioceńskich orzeszków typu *C. betulus*, czy też były one wywołane niejednakowym stopniem fosylizacji.

4. Oprócz typu *C. betulus* spotkałam w Mizernej ok. 4%, a w Krościenku ok. 8% orzeszków inaczej zbudowanych. Na podstawie ich anatomii zaliczyłam je do typu *C. orientalis* (Tablice II i XI, Ryc. 1).

Materiały z Krościenka, które otrzymałam do szczegółowych badań, były uprzednio przesortowane. Do pomiarów biometrycznych użyłam 300 nie uszkodzonych orzeszków, które prof. Szafer zaliczył do gatunków *C. betulus L. foss.* i do *C.* cf. *Tschonoskii.* Złączyłam je w jedną próbę, prof. Szafer wyraził bowiem wątpliwości, czy jego określenie jest dobre i czy małe orzeszki, które zaliczył do gatunku *C.* cf. *Tschonoskii* nie są po prostu drobnoowocową formą *C. betulus* (W. Szafer 1947). Oprócz powyższego materiału znajdowało się w zbiorach Instytutu Botaniki w Krakowie 25 orzeszków, wysortowanych przez prof. Szafera, jako przynależnych do gatunku *Carpinus* cf. *laxiflora.* Zbadałam z nich anatomicznie 6 sztuk. Dwa orzeszki miały budowę *C. betulus*, jeden był podobny do *C. orientalis*, przekroje zaś trzech pozostałych dały obraz dotychczas przeze mnie nie spotykany. Były one cienkościenne, nie sprasowane i miały w przekroju poprzecznym kształt cytryny. Podobny obraz dają przekroje dzisiejszych owoców z gatunku *C. Tschonoskii* i *C. laxiflora* (Tablice II i XI). W tym przypadku oko wprawnego botanika dobrze wyróżniło w większości wysortowanych orzeszków coś odrębnego od gatunku *C. betulus.* Wobec przesortowania materiałów trudno mi powiedzieć, w jakim procencie występował ten typ w lasach plioceńskich, nie mógł on być jednak wysoki.

Oprócz orzeszków wypłukanych w Mizernej z głównego pokładu osadów górnoplioceńskich (Tablice VI i VII), znalazłam w zbiorach Instytutu Botaniki 19 orzeszków pochodzących ze studni, wykopanej w Mizernej w warstwach powierzchownych, znacznie wyżej od pokładów plioceńskich. Liczyłam na to, że znajdę tam może formy pośrednie między plioceńskim gatunkiem typu *C. betulus* a grabami z czwartorzędu. Stan zachowania tych materiałów, zniszczenie perykarpu orzeszków i zupełne pozbawienie perygonu nasunęły mi jednak przypuszczenie, że jest to materiał plioceński znajdujący się może na wtórnym złożu (Tablica VIII).

4. ORZESZKI Z MIOCENU

Miocen był reprezentowany w moich badaniach przez dwie próby. Jedna pochodziła z miocenu środkowego w Gliwicach, druga — prawdopodobnie młodsza — z Domańskiego Wierchu, położonego na południe od Czarnego Dunajca. Z Wieliczki miałam tylko 5 orzeszków, badanie ich mogło więc mieć jedynie znaczenie orientacyjne.

Wynik badań biometrycznych postawił przynależność gatunkową orzeszków z Gliwic i Domańskiego Wierchu pod znakiem zapytania. Orzeszki jednej i drugiej próby były podobne morfologicznie do *C. orientalis*, co wydawało mi się dość dziwne wobec tego, że znajdowano w Polsce dotychczas liczne mioceńskie okrywy *C. betulus*, a nie znaleziono ani jednej okrywy typu *C. orientalis*.

Z osadów tortońskich w Gliwicach zbadałam anatomicznie 13 orzeszków (Tablica XII). Orzeszki te były bardzo sprasowane, jednak uważna obserwacja pod dużym powiększeniem wykazała, że budowa ich była zupełnie podobna do budowy orzeszków z dolnego pliocenu, które zaliczyłam do typu *C. betulus*.

Z Domańskiego Wierchu zbadałam anatomicznie 12 owoców. Stwierdziłam przy tym, że choć ten materiał był zaliczany do górnego miocenu (osady trzeciorzędowe z Domańskiego Wierchu opracowuje dopiero dr M. Łańcucka-Środoniowa), to stopień fosylizacji orzeszków grabu był dalej posunięty, niż w Gliwicach. Były też one więcej zniszczone. Mimo zatartej budowy wewnętrznej stwierdziłam na 7 orzeszkach niechybną przynależność do typu *C. betulus* (Tablica XIII). Reszta była nieoznaczalna z powodu zniszczenia budowy anatomicznej. Możliwe, że niektóre z nich należały do typu *orientalis*.

Stwierdzenie, że w Gliwicach na Śląsku rósł grab typu *C. betulus*, było w zgodzie z obfitym znaleziskiem okryw owocowych tego gatunku w Sośnicy (J. Jentys-Szaferowa 1958). Dziwna się tylko wydawała niezgodność kształtu orzeszków mioceńskich z kształtem orzeszków z Mizernej i Krościenka. W Gliwicach znalazłam bowiem na 225 nie uszkodzonych orzeszków tylko 1 szerszy od swej długości, tj. ok. 0,5%, reszta zaś miała kształt taki jak na Tablicy XII. Na Domańskim Wierchu nie było ani jednego wybitnie szerokiego orzeszka.

Światło pomagające wyjaśnić to zagadnienie rzuciła notatka A. Grossheima, dotycząca grabu kaukaskiego. Autor zbadał 75 orzeszków gatunku *C. betulus* na przestrzeni od dolnego Rodanu po Czernichów, biorąc po jednym owocu z drzewa, oraz analogiczną próbę z Krymu, Kaukazu i Azji Mniejszej i stwierdził, że orzechy tych ostatnich były znacznie węższe i ostrzej zakończone (ryc. 4). To było powodem, że Grossheim uznał grab kaukaski za osobny gatunek, który nazwał *C. caucasica* Grossheim.

Podobną obserwację zrobiłam, badając w r. 1953 orzeszki współczesnych grabów. Zauważyłam wtedy, że im badana próba owoców *C. betulus* leżała bliżej południowych granic zasięgu tego drzewa, tym orzeszki były węższe, i odwrotnie. Podobnie w Szwajcarii, im próba była zbierana wyżej, tym orzeszki były szersze. Orzeszki z terenu Polski były przeciętnie stosunkowo szerokie i tępe (ryc. 5).

Jeżeli tak jest w istocie i jeżeli kształt owoców *Carpinus betulus* jest związany z położeniem geograficznym terenu, w którym to drzewo rośnie, to nie byłoby dziwne że nad Paratetydą, czyli nad zatoką trzeciorzędowego Morza Śródziemnego, w miejscach, z których pochodziły szczątki roślinne znalezione w Gliwicach, rósł w ciepłym klimacie mioceńskim grab, mający taką formę owoców, jaka występuje dziś na najcieplejszych krańcach zasięgu tego drzewa. Jest to oczywiście tylko hipoteza, ale mająca dużą dozę prawdopodobieństwa. Popiera ją fakt, że orzeszki, znajdowane sporadycznie w Sośnicy razem z okrywami typu *C. betulus* miały również kształt wąski i ostro zakończony (Tablica XIV).

Z dolnego miocenu w Wieliczce pokrajałam tylko 1 uszkodzony orzeszek. Ściany jego nie były sprasowane, były jednak bardzo kruche z powodu rozpadania się komórek, co utrudniało zbadanie jego budowy anatomicznej. Nie jest jednak wykluczone, że w Wieliczce występował również typ *C. betulus* (Tablica XIV).

5. ZESTAWIENIE WYNIKÓW

1. Wszystkie zbadane orzeszki z holocenu i z plejstocenu wykazały budowę anatomiczną charakterystyczną dla gatunku *C. betulus.*

2. Orzeszki plioceńskie szersze od swej długości oraz większość orzeszków innego kształtu miały budowę anatomiczną gatunku *C. betulus,* mimo znacznie mniejszych rozmiarów. Analogicznie był zbudowany jeden z 2 dużych orzeszków, znalezionych w dolnym pliocenie w Krościenku (6,4 mm długi). Poza tym znaleziono w pliocenie mały procent orzeszków o budowie charakterystycznej dla gatunków *C. orientalis, C. Tschonoskii* ew. *C. laxiflora.*

3. Orzeszki mioceńskie z Gliwic i znaczna część orzeszków z Domańskiego Wierchu miały budowę charakterystyczną dla gatunku *C. betulus,* mimo że rozmiarami i kształtem przypominały raczej *C. orientalis.* Ponieważ na południowo-wschodnich krańcach dzisiejszego gatunku *C. betulus* występuje forma o wąskich, ostro zakończonych owocach, która jest związana z ciepłym klimatem, przeto jest możliwe, że nad mioceńską zatoką Morza Śródziemnego, gdzie osadzały się nasze materiały mioceńskie, występował również typ *C. betulus* o podobnej formie owoców.

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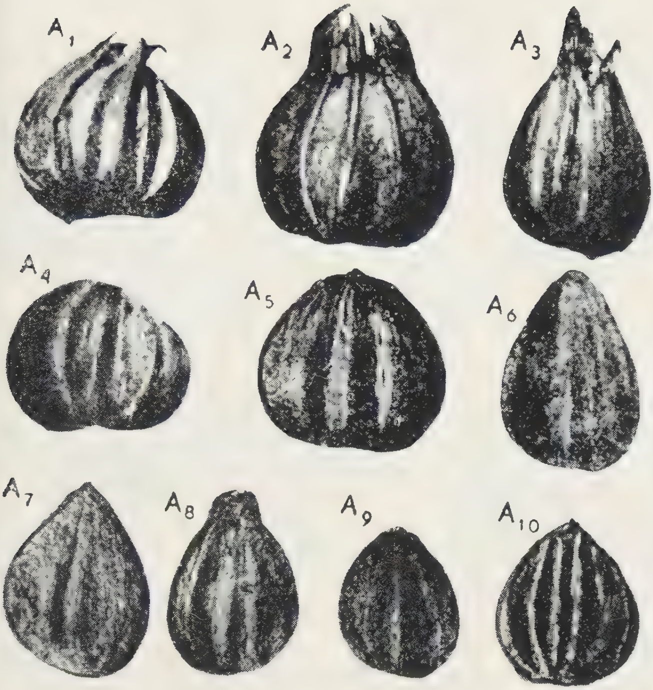
Plate I

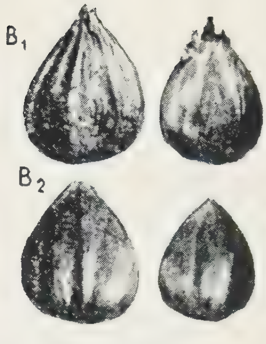
Nutlets from the recent species of the genus *Carpinus*. Magnified × c. 4.
A_1—A_3, B_1—H_1 Nutlets with perigone; A_4—A_6, B_2—H_2 nutlets without perigone; A_7—A_{10} Fossil nutlets

Tablica I

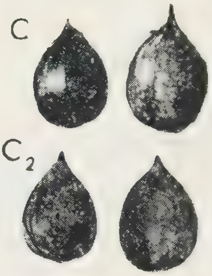
Orzeszki dziś żyjących gatunków rodzaju *Carpinus*. Powiększone ok. 4 ×.
A_1—A_3, B_1—H_1 Orzeszki z perygonem; A_4—A_6, B_2—H_2 Orzeszki bez perygonu; A_7—A_{10} orzeszki kopalne



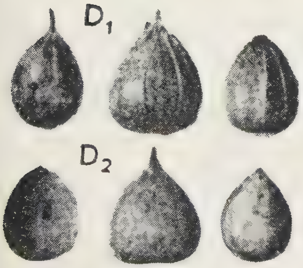
A. *Carpinus betulus*



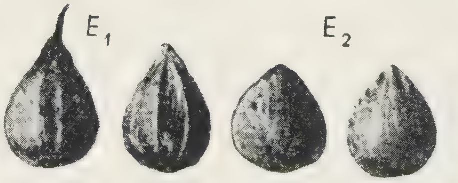
B. *C. caroliniana*



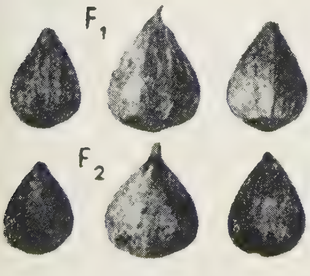
C. *C. orientalis*



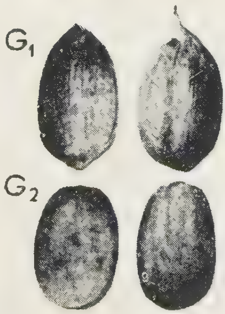
D. *Carpinus laxiflora*



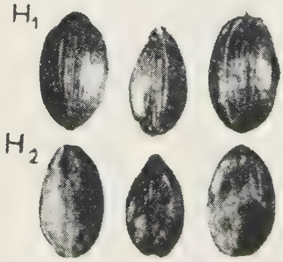
E. *Carpinus Turczaninowii*



F. *C. Tschonoskii*



G *C. cordata*



H. *C. japonica*

Plate II

Transverse sections through nutlets of the recent species of the genus *Carpinus*. Magnified × c. 16.

The breadth of the nutlets corresponds to the average breadth characteristic of the species in question.

Nutlet A is a section of the narrowest nutlet which the author has found of the species *Carpinus betulus*.

Tablica II

Przekroje poprzeczne orzeszków współczesnych gatunków rodzaju *Carpinus*. Powiększone ok. 16 ×.

Szerokość orzeszków odpowiada średnim szerokościom charakterystycznym dla danych gatunków.

Orzeszek A jest przekrojem przez najwęższy orzeszek, jaki autorka spotkała u gatunku *Carpinus betulus*.

Plate II

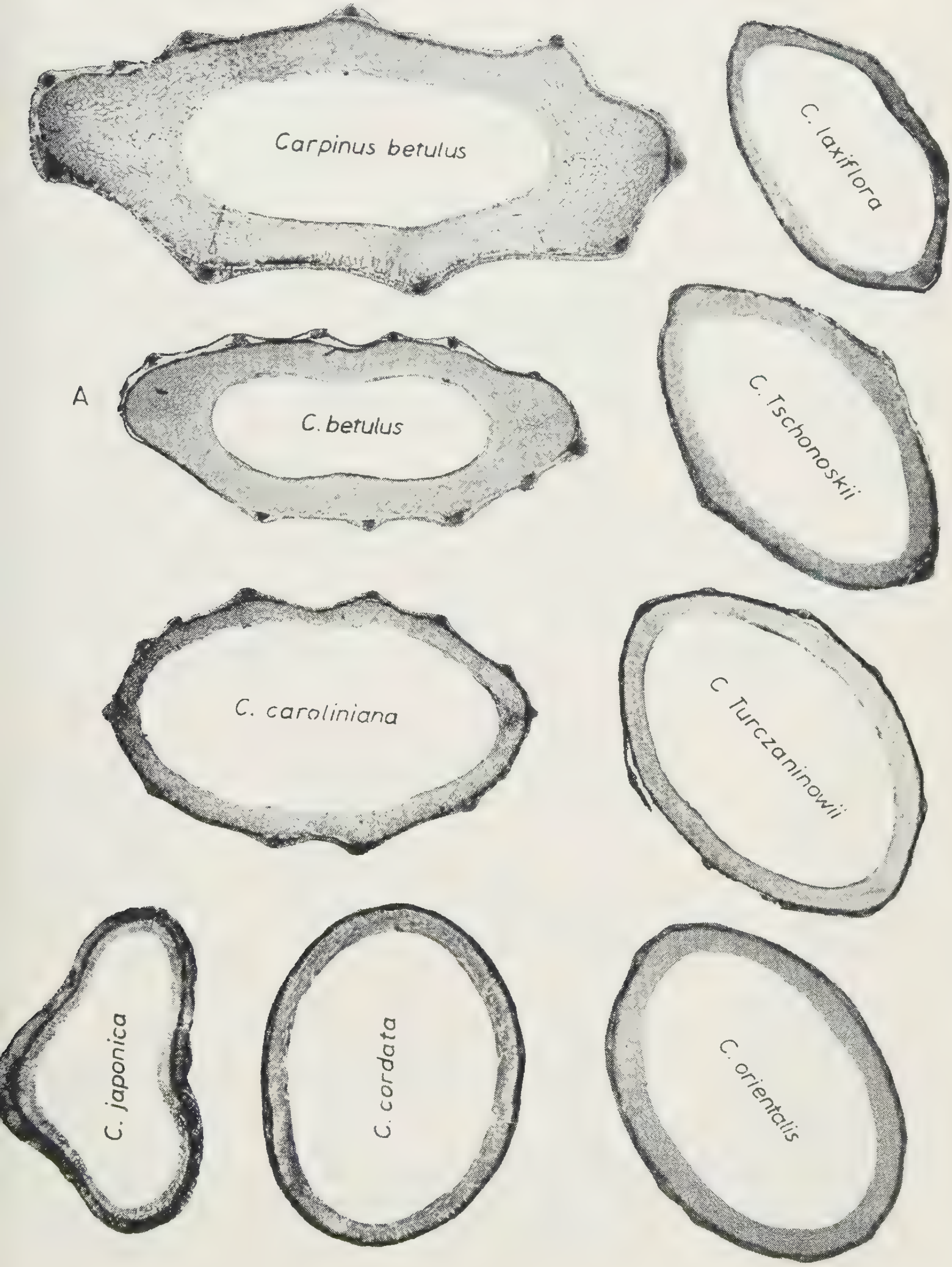

Carpinus betulus
C. laxiflora
A
C. betulus
C. Tschonoskii
C. caroliniana
C Turczaninowii
C. japonica
C. cordata
C. orientalis

Plate III

Nutlets of C. *betulus* from the subfossil deposits at Krzeszów on the San. Nutlets magnified × c. 5, sections × c. 15.

In Plate III the extremes of the length/breadth ratio and of certain other characters are shown.

The nutlets on the left are broader than they are long, the nutlets on the right are 1.5 to 1.7 times longer than they are broad.

Nutlet E is not only an extreme as regards the length/breadth ratio, but also as regards the situation of the broadest part (at 27 per cent of the length) and the apical angle (70°). It is probably maldeveloped. None the less it may be seen from the section that its anatomical structure has characters typical of the species C. *betulus* (cf. Plate II).

A typical character of the nutlets A and B is the absence of ribbing at the broadest part of the pericarp. In addition, nutlet B has not the characteristic thickening of the pericarp on the poles in section (B_2).

The anatomical structure of the pericarp and the thickness of its walls indubitably indicates that all the extremes belong to the species C. *betulus*.

Tablica III

Orzeszki C. *betulus* z osadów subfosylnych z Krzeszowa nad Sanem. Orzeszki powiększone ok. 5. ×, przekroje — ok. 15 ×.

Na tablicy III przedstawiono ekstremy pod względem stosunku długości do szerokości oraz pod względem niektórych innych cech.

Orzeszki z lewej strony są szersze od swej długości, orzeszki z prawej strony są 1,5 do 1,7 dłuższe od swej szerokości.

Orzeszek E jest nie tylko ekstremem pod względem stosunku długości do szerokości, ale pod względem położenia najszerszej części (w 27% długości) i kąta wierzchołka (70°). Jest on prawdopodobnie niedorozwinięty. Niemniej na przekroju widać, że jego budowa anatomiczna ma cechy charakterystyczne dla gatunku C. *betulus* (por. Tablica II).

Cechą charakterystyczną orzeszków A i B jest brak żeberkowania w najszerszym miejscu perykarpu. Poza tym orzeszek B nie ma charakterystycznego zgrubienia perykarpu na biegunach przekroju (B_2).

Budowa anatomiczna perykarpu oraz grubość jego ścian wskazują niechybnie na przynależność wszystkich ekstremów do gatunku C. *betulus*.

Plate III

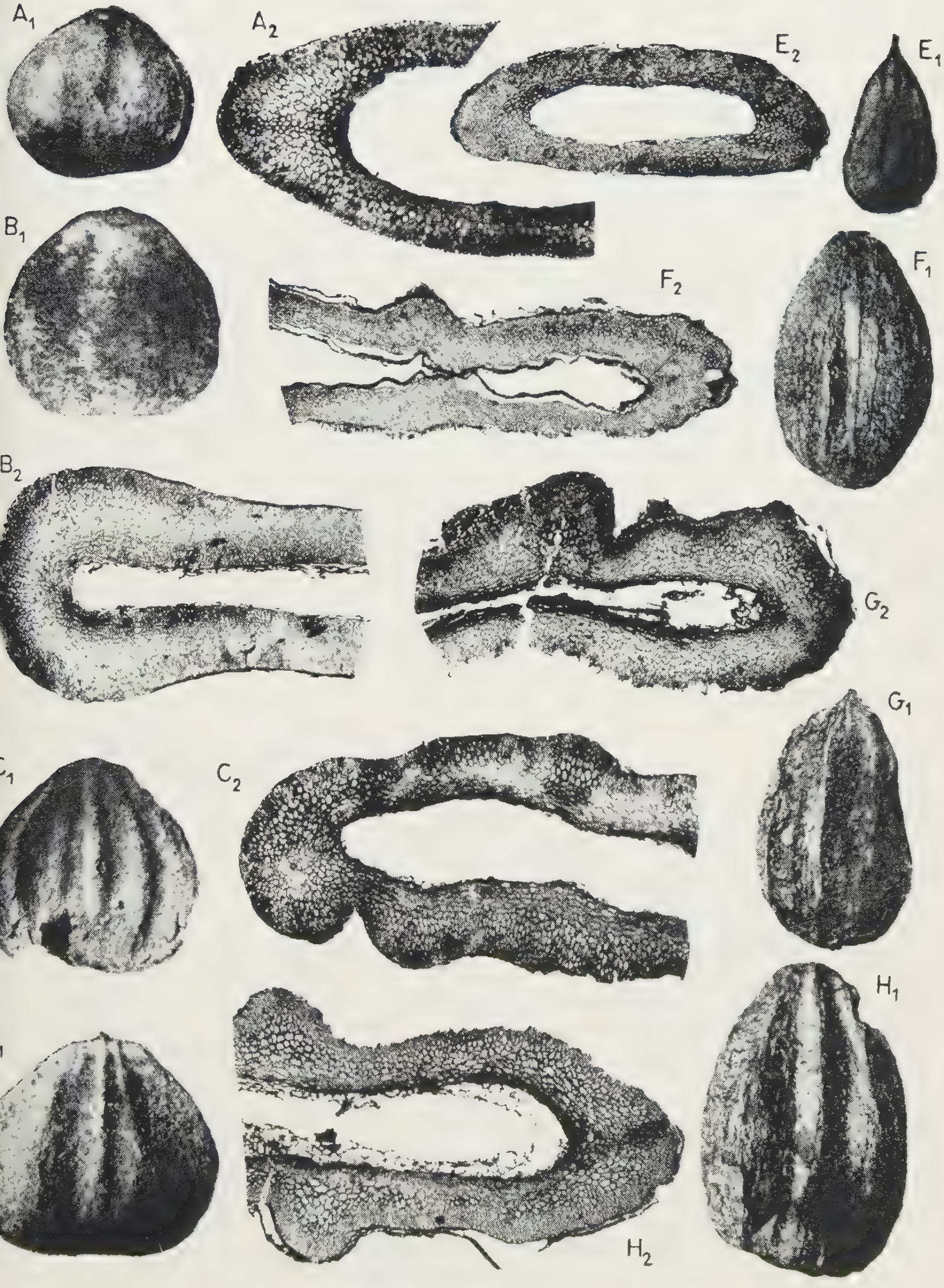


Plate IV

Nutlets of C. *betulus* from the Riss-Würm Interglacial at Samostrzelniki. Nutlets magnified × c. 5, sections of fruits — × c. 15, details of sections — × c. 50.

A — The smallest of the nutlets found, damaged and deformed. The section of the nutlet (A_2) and the magnified detail (A_3) show that it belongs to the species C. *betulus* (uneven thickness of pericarp on the sides of the section, broadening of pericarp on the poles, cells with a large lumen in the medial layer of the pericarp).

B — A nutlet with a damaged perigone. The pericarp is markedly ribbed.

C — A nutlet with the perigone and anatomical structure of the pericarp well preserved. A type with faintly-marked protrusion of the ribs.

D — A nutlet devoid of the perigone, markedly ribbed, and with a very characteristic morphological and anatomical structure.

E — A smooth-surfaced nutlet, deprived of its perigone, without protruding ribs. All the characters typical of C. *betulus* may be seen in the anatomical structure (small palisade cells in the superficial layer, cells with large lumina and undulating walls in the medial layer). Here and there, broadening of the pericarp towards the interior of the nutlet.

Tablica IV

Orzeszki C. *betulus* z interglacjału Riss-Würm w Samostrzelnikach. Orzeszki powiększone ok. 5 ×, przekroje owoców — ok. 15 ×, szczegóły przekrojów — ok. 50 ×

A — Najmniejszy ze znalezionych orzeszków, zniszczony i zdeformowany. Na przekroju orzeszka (A_2) i na powiększonym szczególe (A_3) znać przynależność do gatunku C. *betulus* (niejednakowo gruby perykarp na bokach przekroju, poszerzenie perykarpu na biegunach, komórki z dużym światłem w środkowej warstwie perykarpu).

B — Orzeszek ze zniszczonym perygonem. Perykarp wybitnie żeberkowany.

C — Orzeszek z dobrze zachowanym perygonem i budową anatomiczną perykarpu, typ o słabo wystających żeberkach.

D — Orzeszek pozbawiony perygonu, silnie żeberkowany, o bardzo charakterystycznej budowie morfologicznej i anatomicznej.

E — Orzeszek o powierzchni gładkiej, pozbawiony perygonu, bez wystających żeberek. W budowie anatomicznej widać wszelkie cechy charakterystyczne dla C. *betulus* (drobne, wyciągnięte palisadowo komórki warstwy powierzchniowej, duże światła i faliste ściany komórek warstwy środkowej). Gdzieniegdzie poszerzenie perykarpu ku wnętrzu orzeszka.

Plate IV

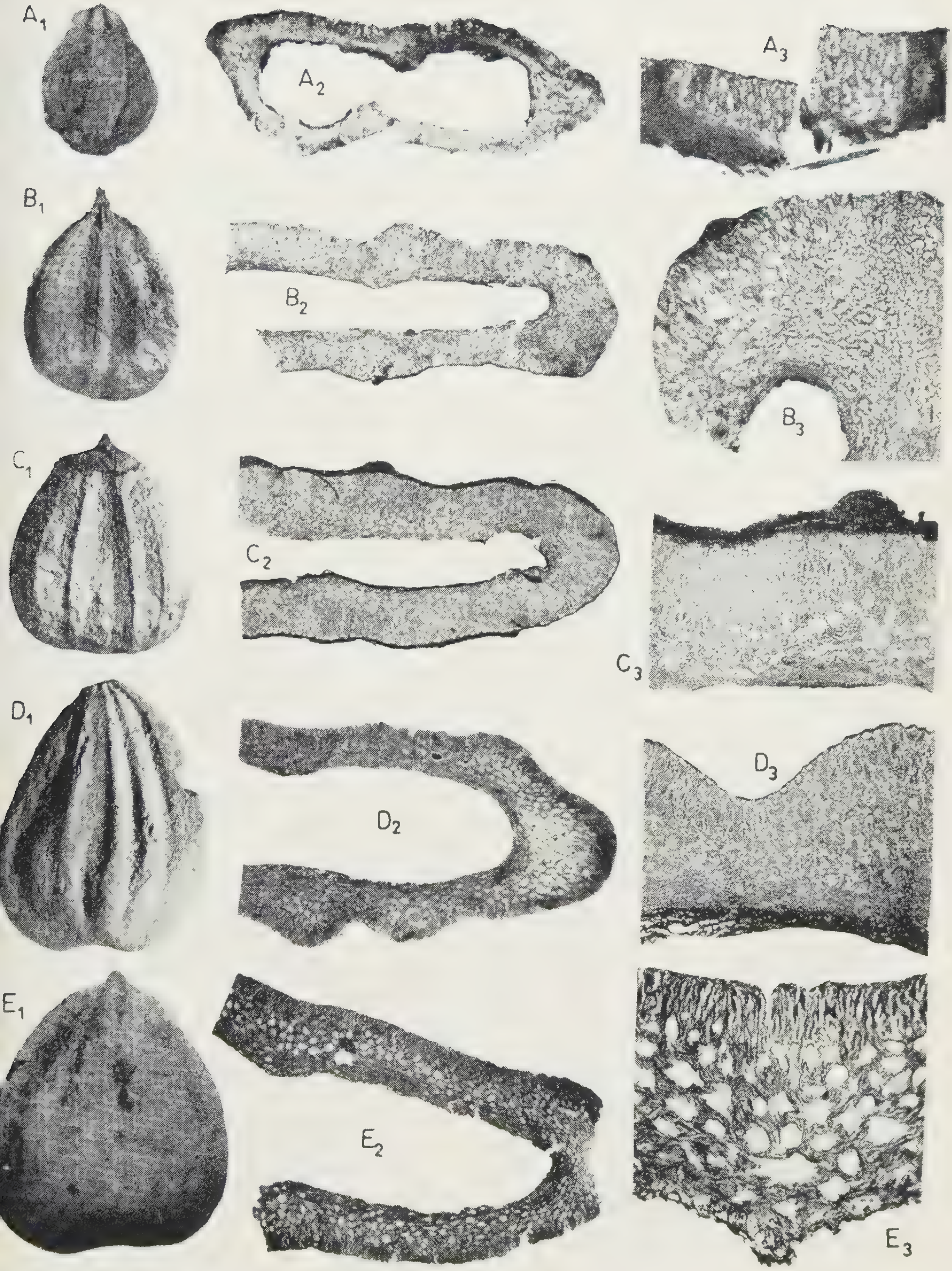


Plate V

Nutlets of C. *betulus* from the Mindel-Riss Interglacial from Olszewice. Magnifications as in Plate IV

As compared with Plate IV the more marked compression of the nutlets shows its main effect on their hollow interior. The walls of the pericarp are not much changed, and all the characters typical of the species C. *betulus* may be clearly seen in them.

Tablica V

Orzeszki C. *betulus* z interglacjału Mindel-Riss z Olszewic. Powiększenia jak na Tablicy IV

W porównaniu z Tablicą IV widać silniejsze sprasowanie orzeszków, które odbija się głównie na ich pustym wnętrzu. Ściany perykarpu są mało zmienione, widać na nich wyraźnie wszystkie cechy charakterystyczne dla gatunku C. *betulus*.

Plate V

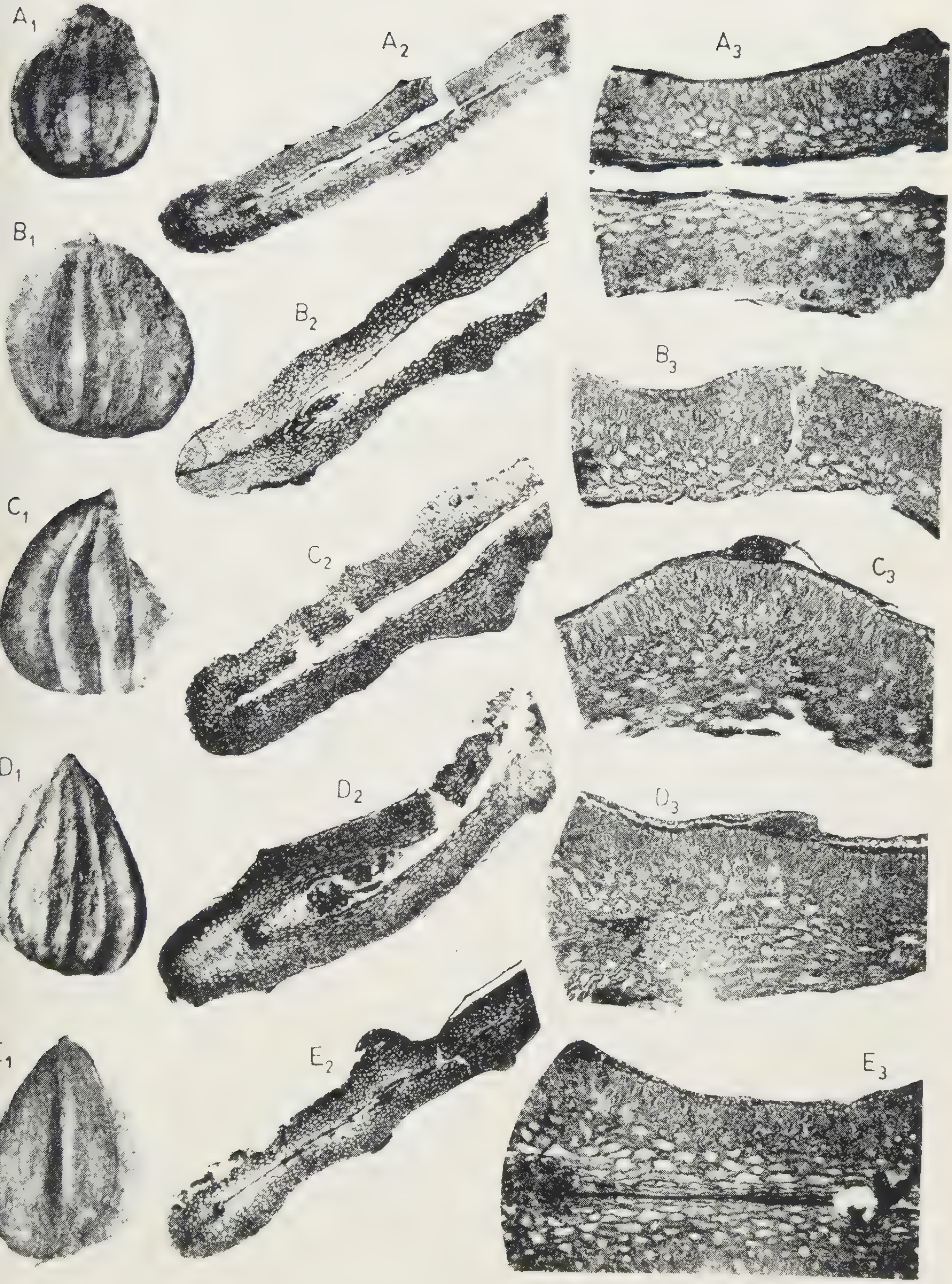


Plate VI

Nutlets of the C. *betulus* type from the Upper Pliocene at Mizerna near Czorsztyn, broader than they are long (cf. Plate IX). Magnifications as in Plates III—V

In the sections of the nutlets there can be seen a more marked compression of the walls of the pericarp than in the nutlets from the Interglacial epochs.

Both the general character of the sections and their anatomical details, magnified × c. 50, give evidence that the nutlets A—F belong to a species of the C. *betulus* type.

The well-preserved perigone on the majority of the nutlets is a proof that they have not been transported very far (cf. Plate VIII).

Tablica VI

Orzeszki typu C. *betulus* z pliocenu górnego w Mizernej koło Czorsztyna szersze od swej długości (por. z Tablicą IX). Powiększenia jak na Tablicach III—V

Na przekrojach orzeszków znać silniejsze sprasowanie ścian perykarpu niż na orzeszkach z interglacjałów.

Zarówno ogólny charakter przekrojów, jak ich szczegóły anatomiczne przedstawione w powiększeniu około 50 × świadczą o przynależności orzeszków A—F do gatunku typu C. *betulus*.

Dobrze zachowany perygon na większości orzeszków jest dowodem, że pochodzą one z niedalekiego transportu (por. z Tablicą VIII).

Plate VI

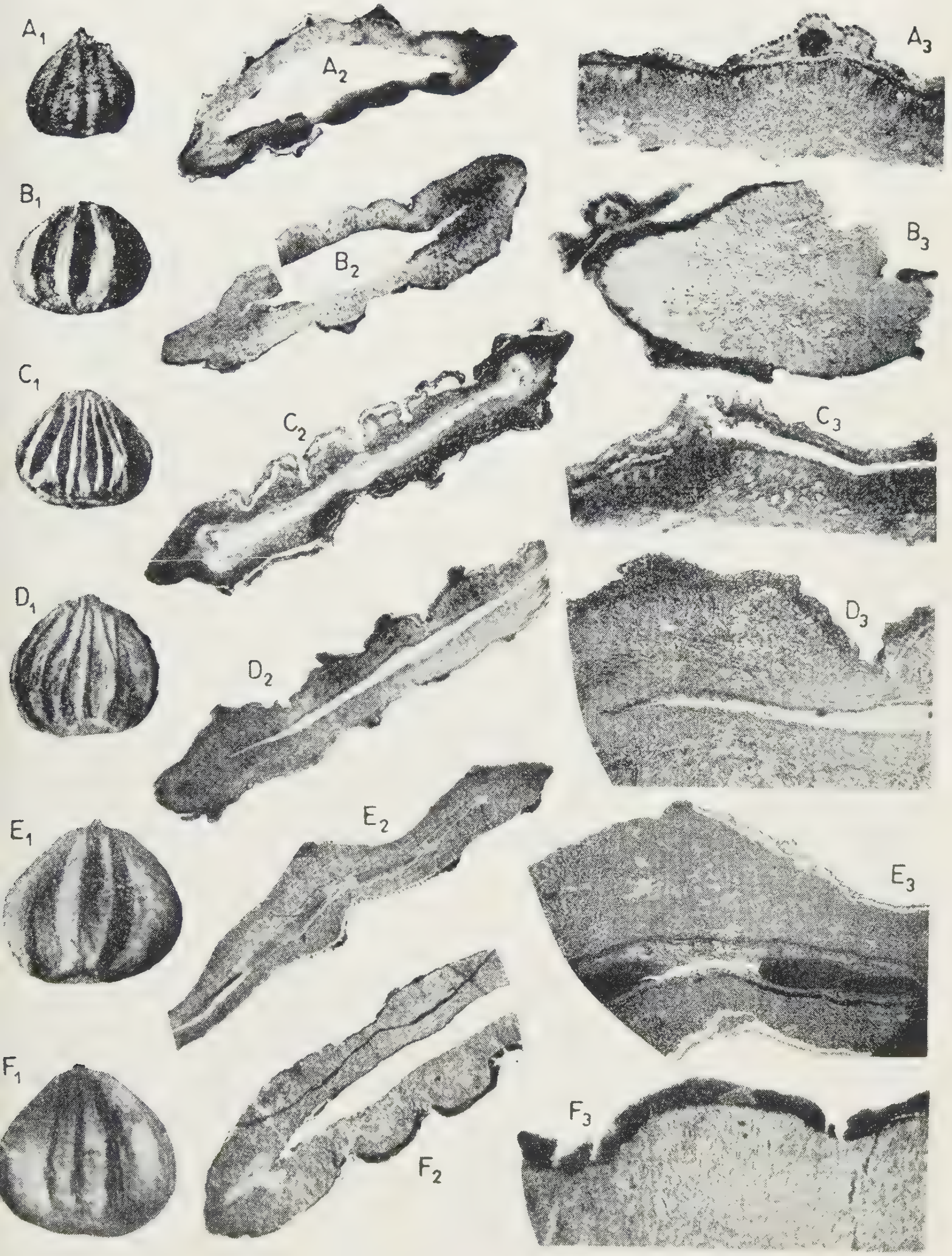


Plate VII

Variability of thickness in the pericarp of nutlets from the Upper Pliocene at Mizerna. Nutlets magnified × c. 5, sections — × c. 15.

By comparing the shape of the nutlets with the accompanying sections of the pericarp, it may be seen that the thickness of the walls of the pericarp is not connected with the shape of the nutlets.

A_1—A_2 The smallest of the nutlets broader than they are long found at Mizerna, 2.4 mm in length.

A—L The *C. betulus* type.

M — The *C. orientalis* type.

Tablica VII

Zmienność grubości perykarpu u orzeszków z górnego pliocenu w Mizernej. Orzeszki powiększone ok. 5 ×, przekroje — ok. 15 ×.

Porównując kształt orzeszków z zamieszczonymi obok przekrojami ich perykarpu widzimy, że grubość ścian perykarpu nie jest związana z kształtem orzeszków.

A_1—A_2 Najmniejszy z orzeszków szerszych od swej długości, znalezionych w Mizernej, 2,4 mm długi.

A—L Typ *C. betulus.*

M — Typ *C. orientalis.*

Plate VII

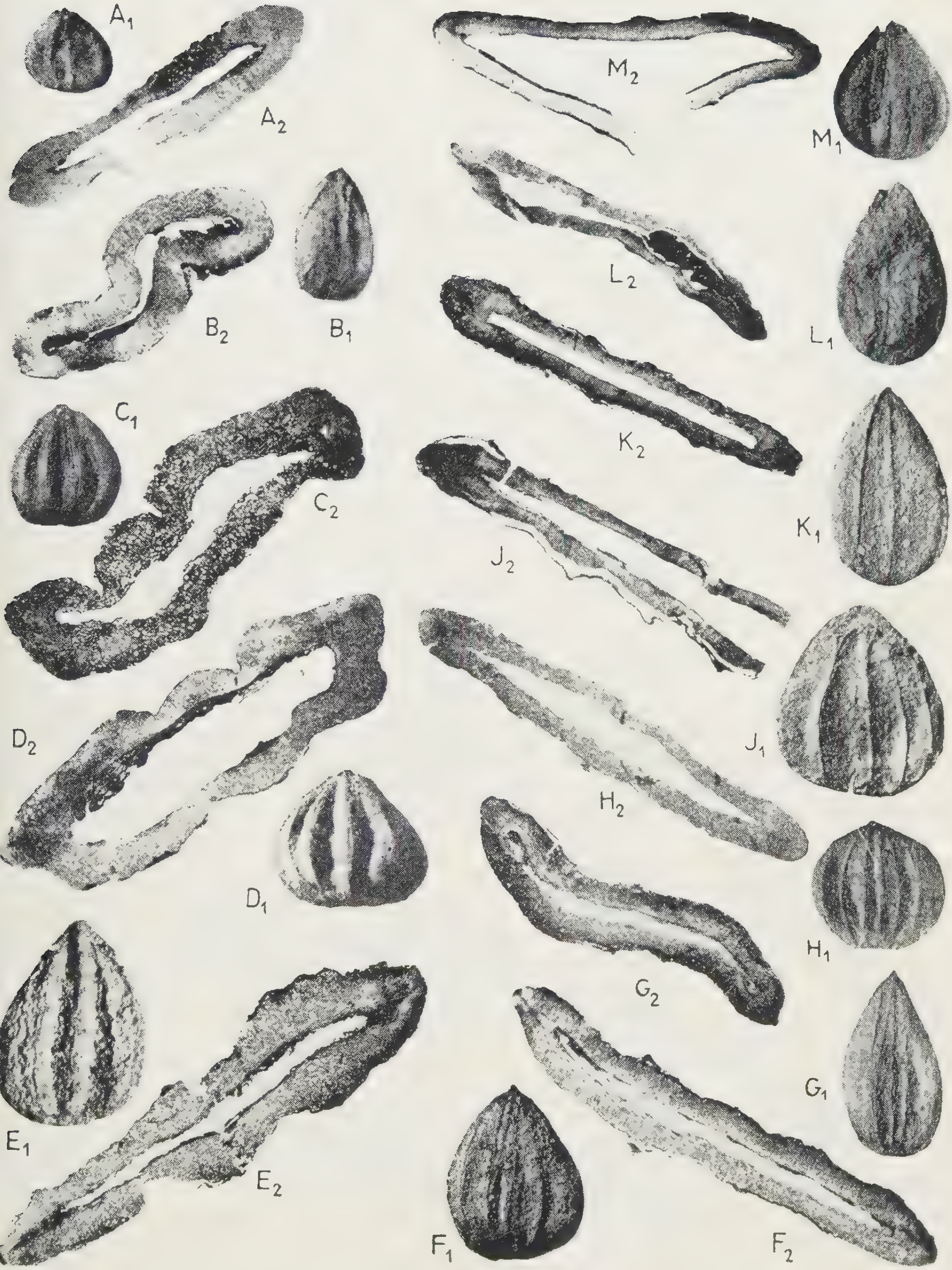


Plate VIII

Nutlets of the C. *betulus* type from a well in the upper strata at Mizerna. Magnification as in Plates III—V

The considerable carbonization of the nutlets, the complete absence of the perigone and the frequently damaged pericarp arouse a supposition that this is a material similar to that in Plates VI and VII, but transported from afar or found in a secondary bed.

Tablica VIII

Orzeszki typu C. *betulus* pochodzące ze studni w górnych warstwach w Mizernej. Powiększenia jak na Tablicach III—V

Silne zwęglenie orzeszków, zupełny brak perygonu i częste zniszczenie perykarpu każą przypuszczać, że jest to materiał analogiczny jak na Tablicach VI i VII, ale pochodzący z dalszego transportu lub znajdujący się na wtórnym złożu.

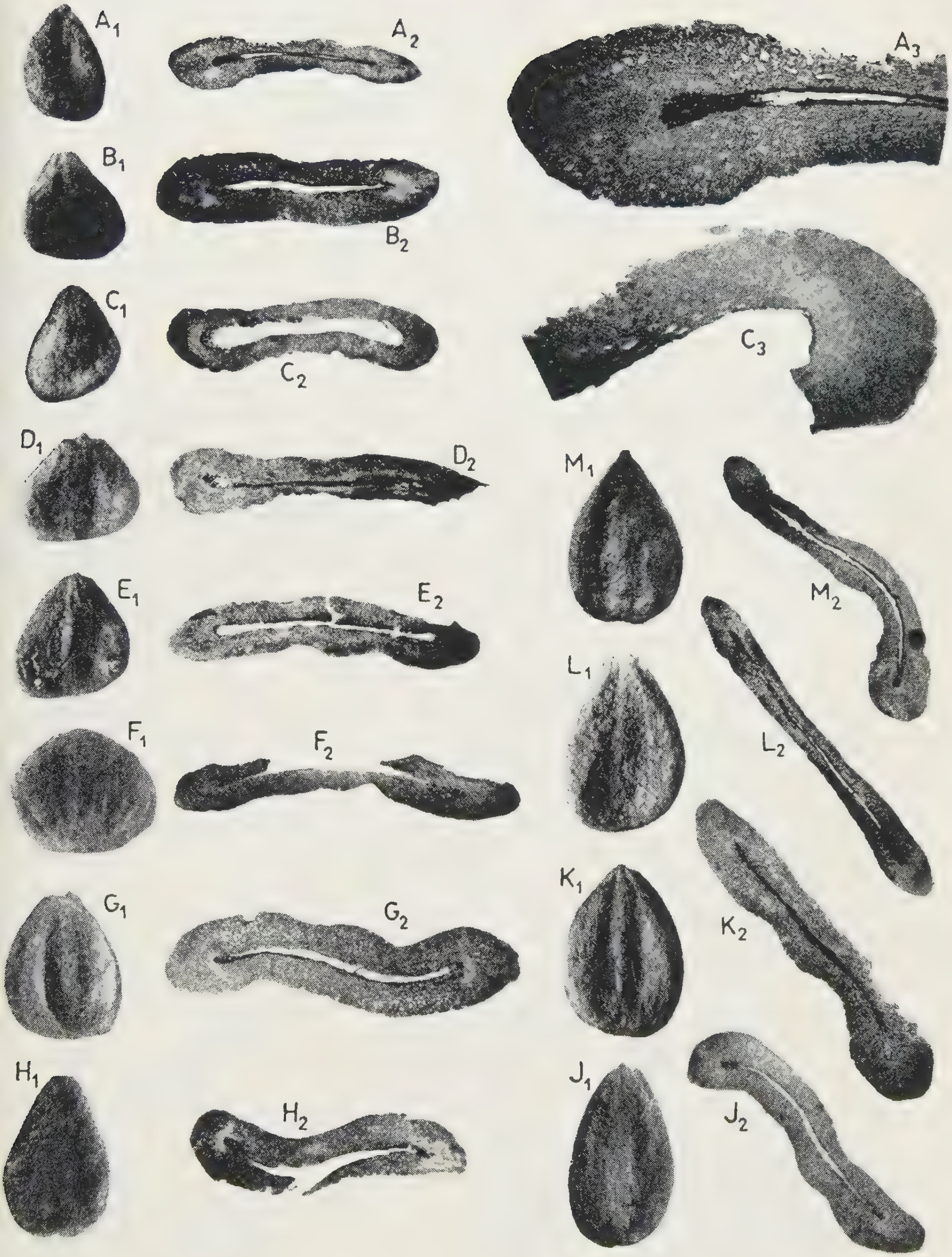

A_1
A_2
A_3
B_1
B_2
C_1
C_2
C_3
D_1
D_2
M_1
M_2
E_1
E_2
L_1
L_2
F_1
F_2
K_1
K_2
G_1
G_2
H_1
H_2
J_1
J_2

Plate IX

Nutlets of the C. *betulus* type from the Lower Pliocene at Krościenko on the Dunajec, broader than they are long. Magnification as in Plates III—VIII

In analogical comparison with the material from the Upper Pliocene at Mizerna (Plate VI), greater compression and further advanced fossilization may be seen in the sections of nuts from Krościenko. In those places where there were cells with large lumina only black marks can as a rule be seen (C_3—G_3).

Attention is called to the thickness of the pericarp on the poles, markedly greater than on the sides in section (C_3—G_3). This is in connection with the monolateral compression of the nutlets (cf. Plate II and Fig. 3).

Tablica IX

Orzeszki typu C. *betulus* z pliocenu dolnego w Krościenku nad Dunajcem, szersze od swojej długości. Powiększenia jak na Tablicach III—VIII

W porównaniu z analogicznym materiałem z pliocenu górnego w Mizernej (Tabl. VI) znać na przekrojach z Krościenka większe sprasowanie orzeszków i dalej posuniętą fosylizację. W miejscach, gdzie znajdowały się komórki o dużych światłach, widać przeważnie tylko ciemne prążki (C_3—G_3).

Zwraca uwagę grubość perykarpu na biegunach przekrojów, która jest znacznie większa niż grubość boków perykarpu (C_3—G_3). Jest to w związku z jednostronnym sprasowaniem orzeszków (por. Tabl. II i ryc. 3).

Plate IX

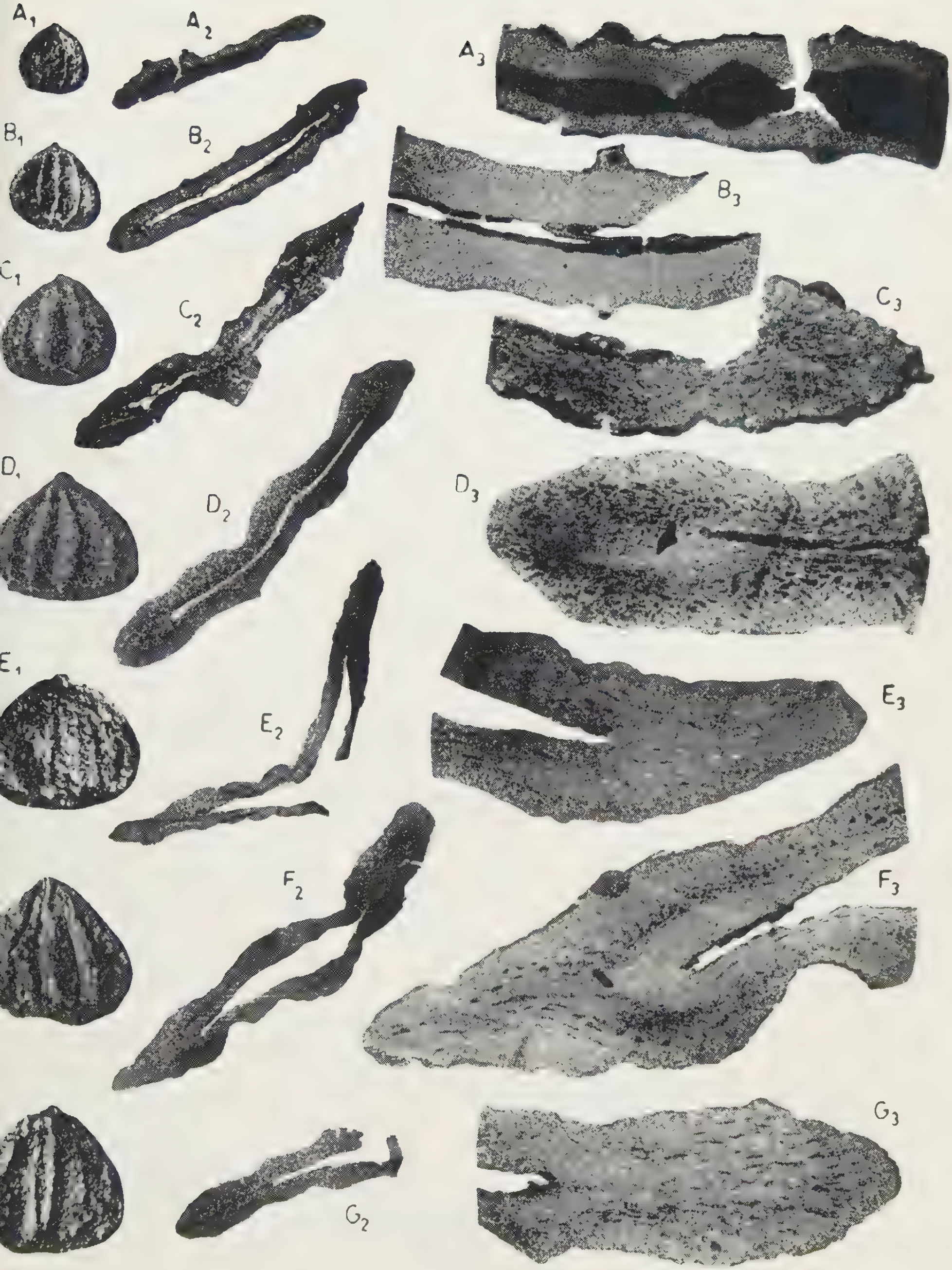


Plate X

Variability of thickness in the pericarp of nutlets from the Lower Pliocene at Krościenko (cf. Plate VII and tables 3, 5). Nutlets magnified × c. 5, sections × c. 15.

Nutlets M and P probably belong to the C. *orientalis* type. The others have been assigned to the C. *betulus* type.

Photographs G_1 and G_2 represent one of the two large nutlets from the Lower Pliocene found at Krościenko. They do not differ in dimensions from the nutlets of the recent species C. *betulus* (v. p. 17).

Tablica X

Zmienność grubości perykarpu u orzeszków z dolnego pliocenu w Krościenku (por. Tablicę VII i tabele 3 i 5). Orzeszki powiększone ok. 5 ×, przekroje — ok. 15 ×

Orzeszki M i P należą prawdopodobnie do typu C. *orientalis*. Pozostałe orzeszki zostały zaliczone do typu C. *betulus*.

Fotografie G_1 i G_2 przedstawiają jeden z dwóch dużych orzeszków znalezionych w pliocenie dolnym w Krościenku. Nie różniły się one rozmiarami od orzeszków współczesnego gatunku C. *betulus* (patrz str. 17).

Plate X

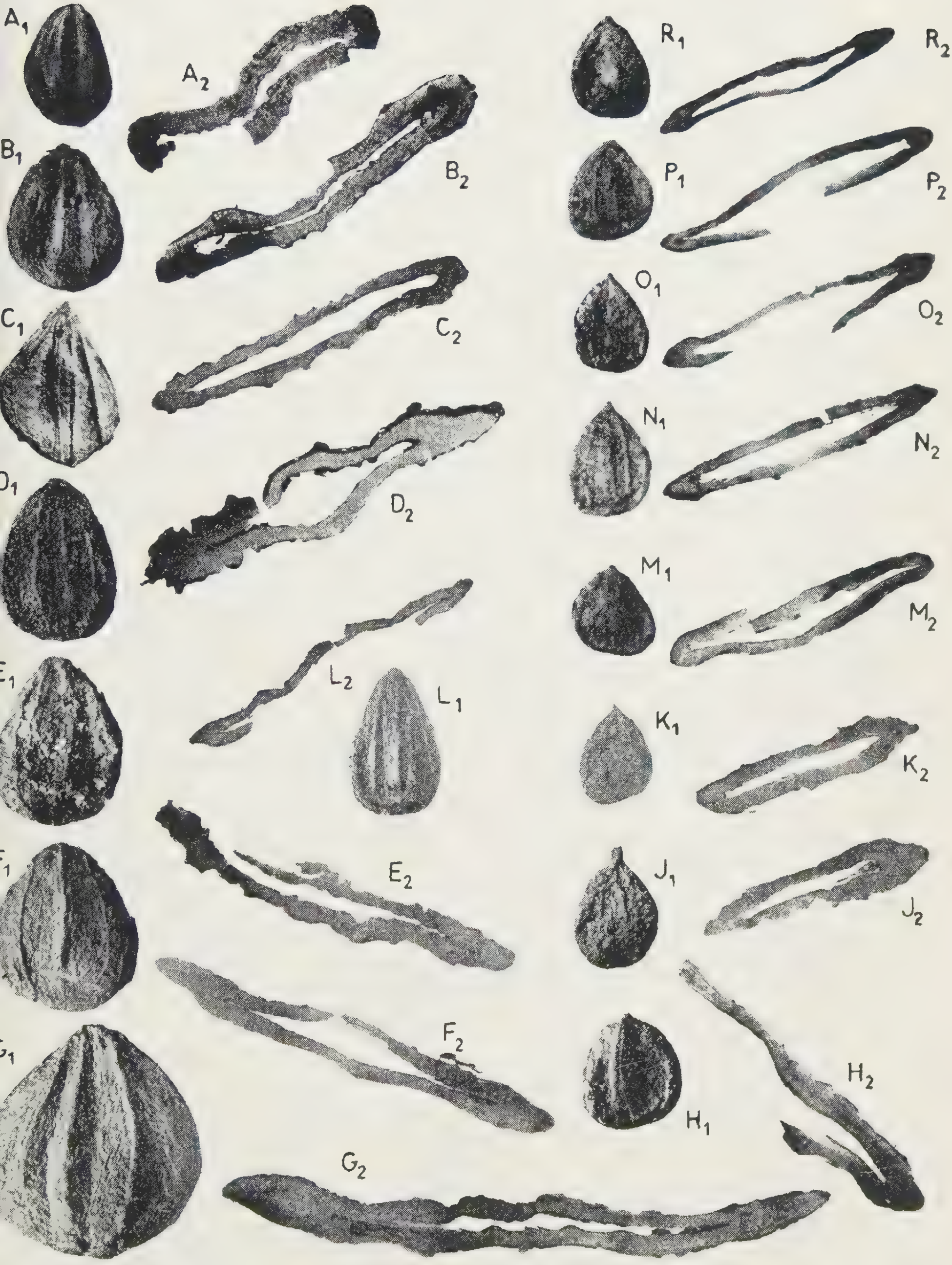

A_1
A_2
B_1
B_2
C_1
C_2
D_2
L_2
L_1
E_2
F_2
G_2
R_1
R_2
P_1
P_2
O_1
O_2
N_1
N_2
M_1
M_2
K_1
K_2
J_1
J_2
H_2
H_1

Plate XI

Morphological and anatomical types of Pliocene hornbeam nuts

The photographs in Plate XI have been given to show that it is difficult to determine the species of fossil nutlets on the basis of the morphology alone.

I. Recent nutlets

A — Transverse section of a nutlet of *C. betulus*. Magnified × c. 20.
B — Transverse section of a nutlet of *C. orientalis*. Magnified × c. 50.

II. Fossil nutlets

Nutlets magnified × c. 5, sections × c. 15, and details of sections × c. 50.

Upper Pliocene (Mizerna)

B_1—B_3 Nutlet c. 4 mm in length, *C. betulus* type
E_1—E_3 Nutlet c. 4 mm in length, *C. orientalis* type

Lower Pliocene (Krościenko)

C_1—C_3 Nutlet c. 2.5 mm in length, *C. betulus* type
F_1—F_3 Nutlet c. 2.4 mm in length, *C. orientalis* type
G_1—G_3 Nutlet c. 3.5 mm in length, *C. Tschonoskii* or *C. laxiflora* type.

Tablica XI

Typy morfologiczne i anatomiczne plioceńskich orzeszków grabu

Fotografie zestawione na Tablicy XI mają na celu wykazanie, że na podstawie samej morfologii orzeszków kopalnych trudno jest określić gatunek, do jakiego należą.

I. Orzeszki współczesne

A — Przekrój poprzeczny przez orzeszek *C. betulus*. Powiększony ok. 20 ×.
B — Przekrój poprzeczny przez orzeszek *C. orientalis*. Powiększony ok. 50 ×.

II. Orzeszki kopalne

Orzeszki powiększone ok. 5 ×, przekroje ok. 15 ×, szczegóły przekrojów ok. 50 ×.

Pliocen górny (Mizerna)

B_1—B_3 Orzeszek ok. 4 mm długi, typ *C. betulus*
E_1—E_3 Orzeszek ok. 4 mm długi, typ *C. orientalis*

Pliocen dolny (Krościenko)

C_1—C_3 Orzeszek ok. 2,5 mm długi, typ *C. betulus*
F_1—F_3 Orzeszek ok. 2,4 mm długi, typ *C. orientalis*
G_1—G_3 Orzeszek ok. 3,5 mm długi, typ *C. Tschonoskii* lub *C. laxiflora*

Plate XI

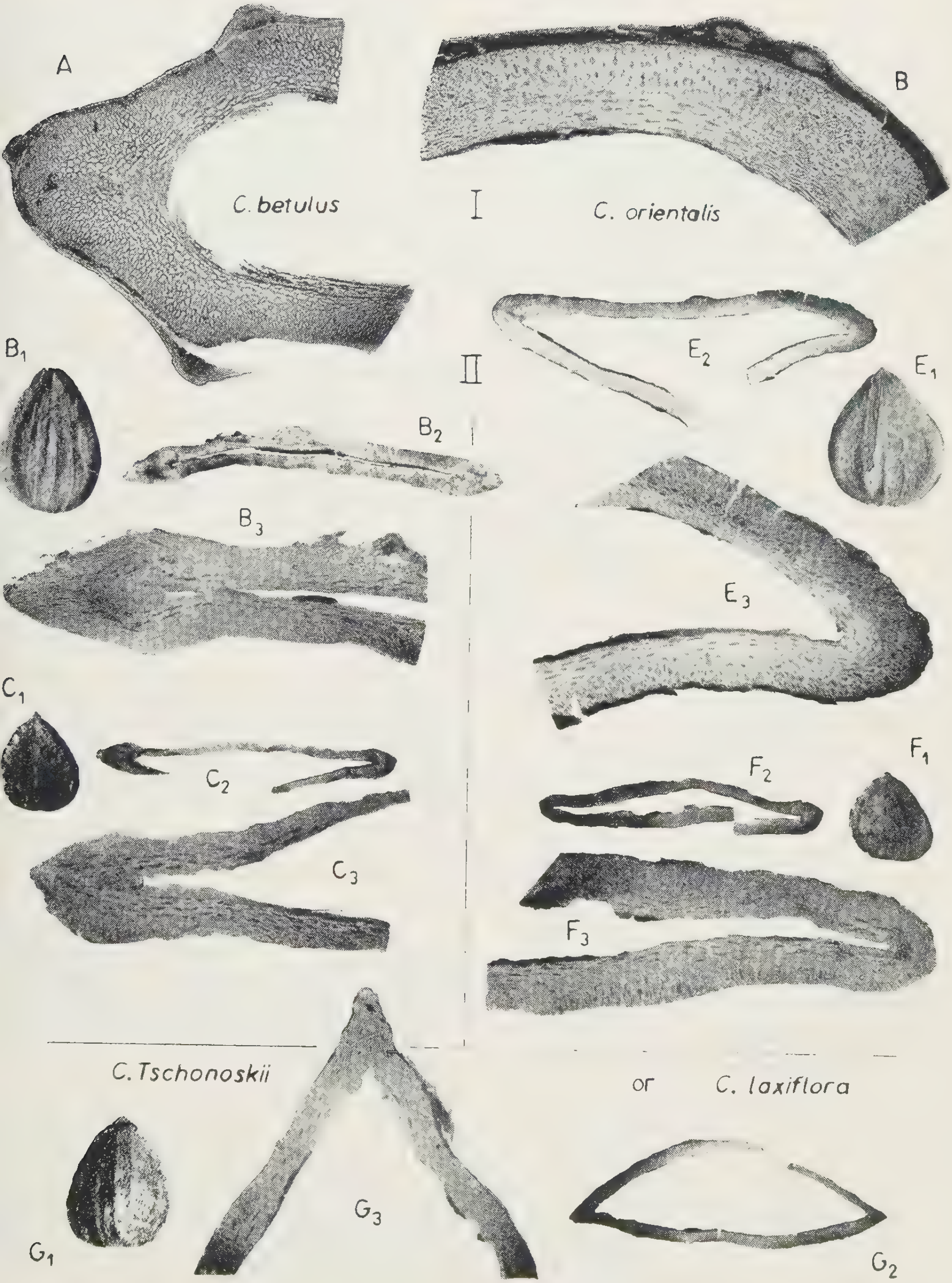

A
B
C. betulus
I
C. orientalis
B$_1$
II
E$_2$
E$_1$
B$_2$
B$_3$
E$_3$
C$_1$
C$_2$
F$_2$
F$_1$
C$_3$
F$_3$
C. Tschonoskii
or
C. laxiflora
G$_3$
G$_1$
G$_2$

Plate XII

Hornbeam nutlets from the Middle Miocene at Gliwice. Magnifications as in Plates III—V

A_1—A_3 Single nutlet broader than long, found at Gliwice, C. *betulus* type.

B — K Narrow sharp-ended nutlets. It may clearly be seen from the sections that they belong to the C. *betulus* type.

Tablica XII

Orzeszki grabu ze środkowego miocenu w Gliwicach. Powiększenia jak na Tablicach III—V

A_1—A_3 Jedyny orzeszek szerszy od swej długości, znaleziony w Gliwicach, typ C. *betulus*.

B — K Orzeszki wąskie, ostro zakończone. Na ich przekrojach widać wyraźnie przynależność do typu C. *betulus*.

Plate XII

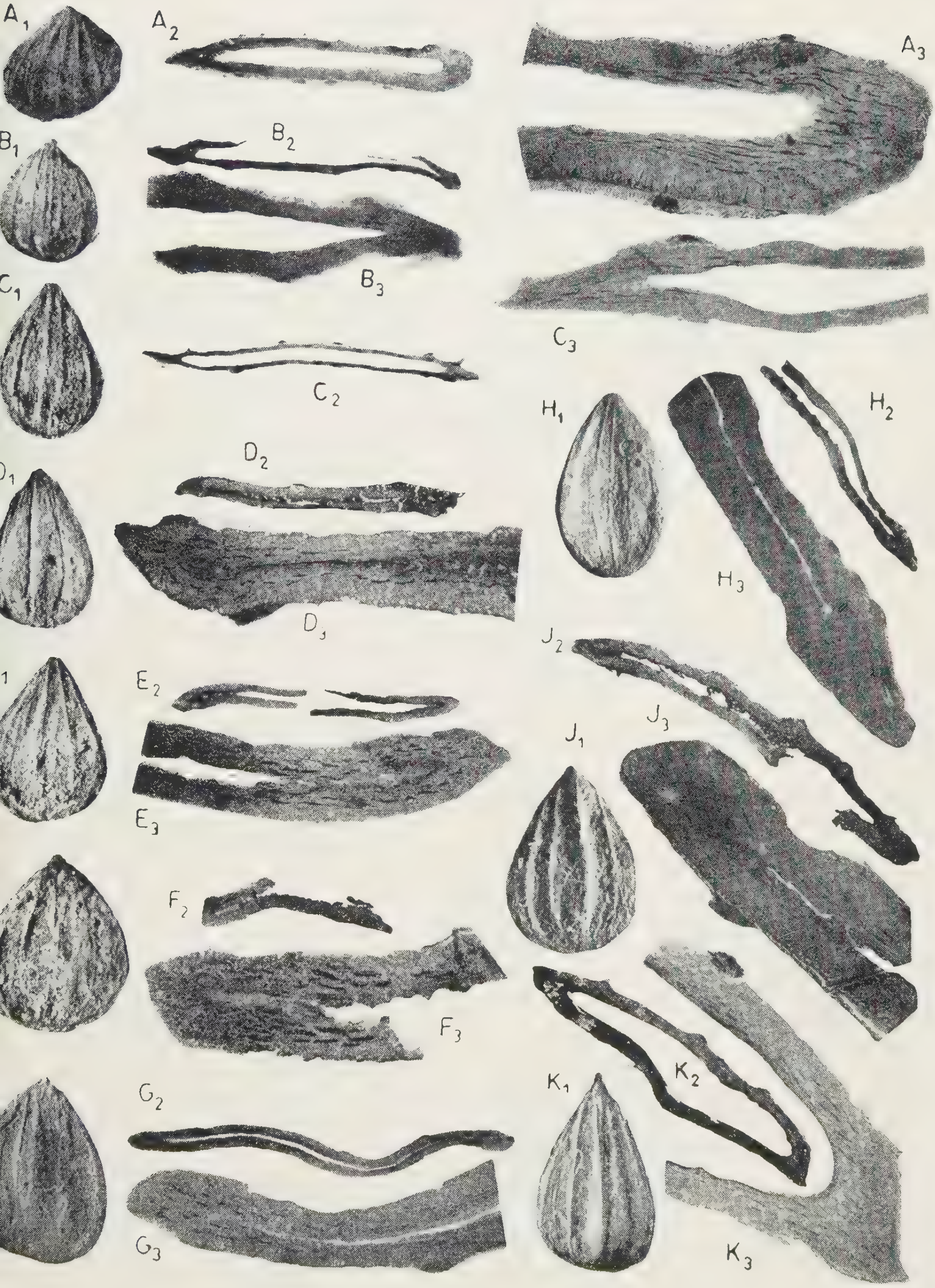

A_1
A_2
A_3
B_1
B_2
B_3
C_1
C_2
C_3
D_2
D_3
E_2
E_3
F_2
F_3
G_2
G_3
H_1
H_2
H_3
J_2
J_3
J_1
K_1
K_2
K_3

Plate XIII

Nutlets from the Upper Miocene on Domański Wierch. Magnification as in Plates III—V

Damaged and much compressed nutlets, often with the perigone torn. Anatomical structure indistinct.

The sections D_3—F_3 and H_3—L_3 can be seen to belong to the *C. betulus* type.

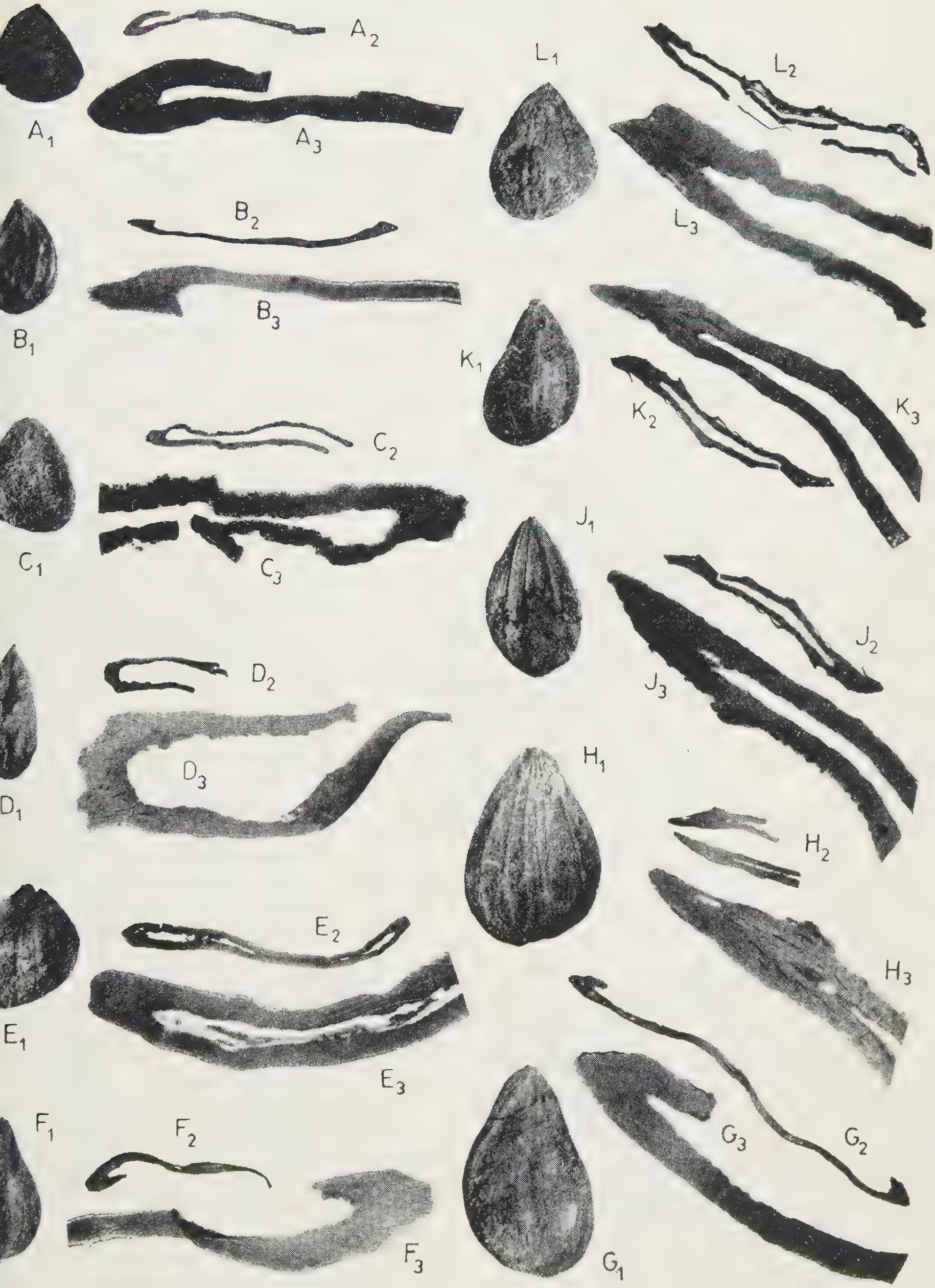
Tablica XIII

Orzeszki z górnego miocenu na Domańskim Wierchu. Powiększenia jak na Tablicach III—V

Orzeszki zniszczone, silnie sprasowane, często z obtartym perygonem. Budowa anatomiczna na ogół niewyraźna.

Na przekrojach D_3—F_3 i H_3—L_3 znać przynależność do typu *C. betulus*.

Plate XIII



A2
A1
A3
L1
L2
L3
B2
B3
B1
K1
K2
K3
C2
C1
C3
J1
J2
J3
D2
D3
D1
H1
H2
H3
E2
E1
E3
F1
F2
F3
G3
G2
G1

Plate XIV

Above, recent nutlets of *C. betulus* L. *v. caucasica* Grossheim. Magnified × c. 5.
Below, nutlets of the *C. betulus* type from the Polish Miocene. Magnified × c. 5.
A — Section of a nutlet of *Carpinus polonica* Zabłocki from Wieliczka.

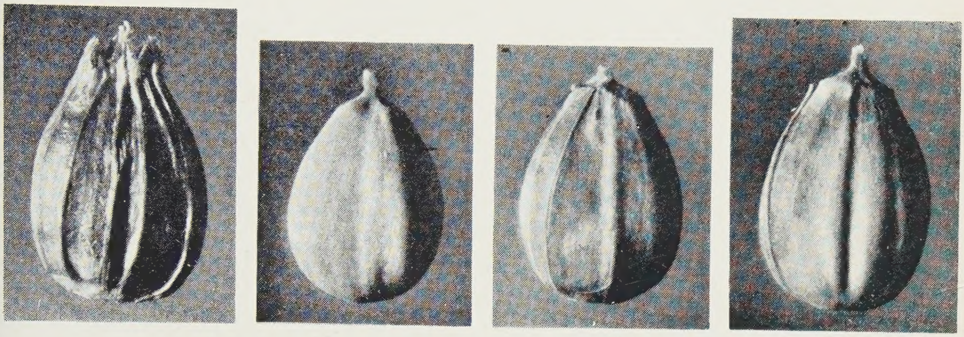
Tablica XIV

U góry współczesne orzeszki *C. betulus* L. *v. caucasica* Grossheim. Powiększone ok. 5 ×.

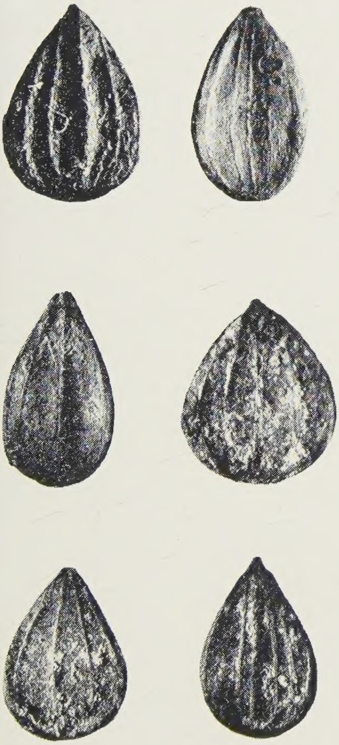
U dołu orzeszki typu *C. betulus* z polskiego miocenu. Powiększone ok. 5 × .

A — Przekrój orzeszka *Carpinus polonica* Zabłocki z Wieliczki.

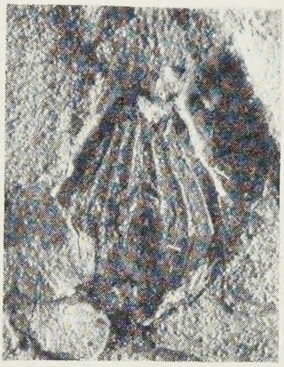
Carpinus betulus L. *v. caucasica* A. Grossh.



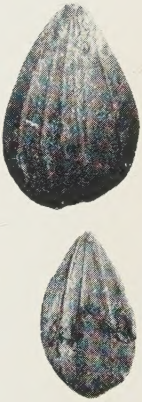
Carpinus betulus type from the Polish Miocene



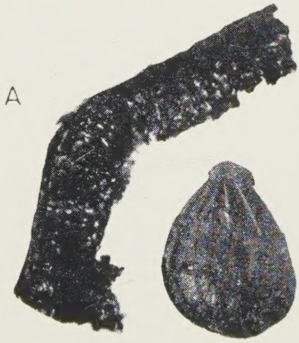
Gliwice



Sośnica



Domański Wierch



Wieliczka

Cena zł 14,—